Palestine Polytechnic University

College Of Engineering And Technology

Mechanical Engineering Department

Graduation Project

Design And Implementation Of Balance Testing Machine For Grinding And Cut-Off Wheels

Project Team

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Abstract

Cut off wheels and grinding discs are one of the most important tools used in the construction and industrial works, the discs available in different diameter and can be operated at different rotational speeds ranging from 4000-15000rpm depending on the size of the used disc and the nominal speed of the used electric cutting machine.

Usually, the new discs may not be completely balanced,sometimes the production process of the discs result in small unbalance (improper mass distribution of the discs), this unbalance can result in significant centrifugal force on the cutting machine especially at high speed, even though the existing unbalance in the discs is small, because the resulted force is proportional to the square value of the rotational speed ($f=Mew^2$).

This unbalance in the discs usually not detectable by eye, or by using the regular weighting devices,therefore the idea behind this project is to design mechatronics equipment that is able to discover the amount and location of the discs during their manufacture, in the order to let the worker to repairthem by material compensation.

The new device is working to benefit the Jelanco company in Hebron to improve the quality tests of their products, The new device consists from three load cells,the load cells are distributed on triangular form, where weight of disc affect on it, so output signals are not the same, difference in values of signals that means simply the disc is unbalance, so three equations was applied and get three results as following: total mass of disc, location and quantity of mass must be added to make disc is balanced, the results can be shown in digital display like as LCD or monitor.

The device has accurate values, precise and fast. The operator error has no effect on its output.

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Chapter one

Introduction

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1.1.1 Background of grinding and cut off wheels

In earlier times, only natural abrasives were available. From about the beginning of this century, however, manufactured abrasives, primarily silicon carbide and aluminum oxide, have replaced the natural materials; even natural diamonds have been almost completely supplanted by synthetics. Superior and controllable properties and dependable uniformity characterize the manufactured abrasives.

Both silicon carbide and aluminum oxide abrasives are very hard and brittle. This brittleness, called friability, is controllable for different applications. Friable abrasives break easily, thus forming sharp edges. This decreases the force needed to penetrate into the work material and the heat generated during cutting. Friable abrasives are most commonly used for precision and finish grinding. Tough abrasives resist fracture and last longer. They are used for rough grinding, snagging, and off-hand grinding.

Abrasive grains are hard crystals either found in nature or manufactured. The most commonly used materials are aluminum oxide, silicon carbide, cubic boron nitride and diamond. Other materials such as garnet,zirconia, glass and even walnut shells are used for some applications.

The applications for abrasive processes are multiple and varied. They include:

1) Cleaning of surfaces, also the coarse removal of excess material—such as rough offhand grinding in foundries to remove gates and risers.
2) Shaping, such as in form grinding and tool sharpening.
3) Sizing, a general objective, but of primary importance in precision grinding.
4) Surface finish improvement, either primarily as in lapping, honing, and polishing or as a secondary objective in other types of abrasive processes.

5) Separating, as in cut-off or slicing operations.

The main field of application of abrasive processes is in metal working, because of the capacity of abrasive grains to penetrate into even the hardest metals and alloys.

As a general rule, although subject to variation:

1) Aluminum oxide abrasives are used for grinding plain and alloyed steel in a soft orhardened condition.
2) Silicon carbide abrasives are selected for cast iron, nonferrous metals, and nonmetallic materials.
3) Diamond is the best type of abrasive for grinding cemented carbides. It is also used for grinding glass, ceramics, and hardened tool steel.

1.1.2 Bond Properties and Grinding Wheel Grades

The four main types of bonds used forgrinding wheels are the vitrified, Resinoid, rubber, and metal.

1) *Vitrified bonds* are used for more than half of all grinding wheels made, and are preferred because of their strength and other desirable qualities.however, are more sensitive to impact than those made with organic bonds.
2) *Resinoid bonds* are selected for wheels subjected to impact, or sudden loads, or very high operating speeds.
3) *Rubber bonds* are even more flexible than the resinoid type, and for that reason are used for producing a high finish and for resisting sudden rises in load.

4) *Metal bonds* are used in CBN and diamond wheels. In metal bonds produced by electrode position, a single layer of super abrasive material (diamond or CBN) is bonded to a metal core by a matrix of metal, usually nickel.

In addition to the basic properties of the various bond materials, each can also be applied in different proportions, there by controlling the grade of the grinding wheel.

Grinding wheel grades commonly associated with hardness, express the amount of bondmaterial in a grinding wheel, and hence the strength by which the bond retains the individualgrains.

1.1.3American National Standard Grinding Wheel Markings

ANSI Standard B74.13-1990" Markings for Identifying Grinding Wheels and Other Bonded Abrasives".

Sequence of Markings

	1	2	3	4	5	6
Prefix	Abrasive Type	Grain Size	Grade	Structure	Bond Type	Manufacturer's Record
51 –	A –	36 –	L –	5 –	V –	23

The meaning of each letter and number in this or other markings is indicated by the following complete list.

Prefix: The prefix is a manufacturer's symbol indicating the exact kind of abrasive. Its use is optional.

1) Abrasive Letters: The letter (A) is used for aluminum oxide, (C) for silicon carbide,and (Z) for aluminum zirconium. The manufacturer may designate some particular type in any one of these broad classes, by using his own symbol as a prefix.
2) Grain Size: The grain sizes commonly used and varying from coarse to very fine are indicated by the following numbers: 8, 10, 12, 14, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, and 220. The following additional sizes are used occasionally: 240,280, 320, 400, 500, and 600. The wheel manufacturer may add to the regular grain number an additional symbol to indicate a special grain combination.
3) Grade: Grades are indicated by letters of the alphabet from A to Z in all bonds or processes. Wheel grades from A to Z range from soft to hard.
4) Structure: The use of a structure symbol is optional. The structure is indicated by Numbers from 1 to 16 (or higher, if necessary) with progressively higher numbers indicating a progressively wider grain spacing (more open structure).
5) Bond or Process: Bonds are indicated by the following letters: V, vitrified; S, silicate;E, shellac or elastic; R, rubber; RF, rubber reinforced; B, Resinoid (synthetic resins); BF,Resinoid reinforced; O, oxychloride.
6) Manufacturer's Record: The sixth position may be used for manufacturer's privatefactory records; this is optional.[2]

1.1.4Cut –off wheels Labelcodes, ordering instruction

Each cut-off wheel and grinding discs have its own label shown in Figure (1. 1) those labels have codes which determine the characteristics of the wheel such as type, shape,abrasive type code,grains size, grad (wheel properties), bond and maximum operating speed.

The following code 41 A 46 R BF 80 described in table (1.1)

Table (1.1):Example of Cut –off wheels Label codes

code	41	A	46	R	BF	80
characteristics	Flat type	Aluminum oxide	Grit size	hardness	Fiber reinforced Resinoid bond	Operating speed

Figure (1.1):Label code

1.2.1 Manufacturing of Grinding and Cut -Off Wheels Discs in Jelanco Factory

The final product "Discs" is moved through many steps start by restrict type of product and size of grains "grinding or cutting" this is important to choose the raw material, so in Jelanco factory two types of raw materials, the first is Aluminum oxide abrasives are used for grinding and cutting metal sheets, steel, alloyed and the second is Silicon carbide abrasives selected for cast iron, nonferrous metals, and nonmetallic materials such as " stones " see(figure 1.2, 1.3) , and not that if grains is large "coarse" number of size is small.

After selecting the type, quantities and size of grains,the grains are mixed with bonds using a rotary mixer , there is two types of bonds, the first stage is to mix material with liquid bond its called Resinoid Oil , the second type is powder bonds, see (figure 1.4 , 1.5).

Then take the mixture for refinement from waste and defect, after that come to formation, the formation process passed through three steps: put ring , label, reinforcement net "to protect material and give uniform surface for discs ", then put all of them in molds under pressure 200bar nearly, as shown in figure (1.6).

After formation of the disc, as shown in Figure(1.7), comes of the balance testing operation and weighting, this operation is implemented by a mechanism and electronic Libra to measure weight of the disc as in figure (1.8, 1.9) respectively.

Finally, the discs are collect on groups and put in container prelusion to place in oven for 24 hours on limiting temperature degrees as infigure (1.10).

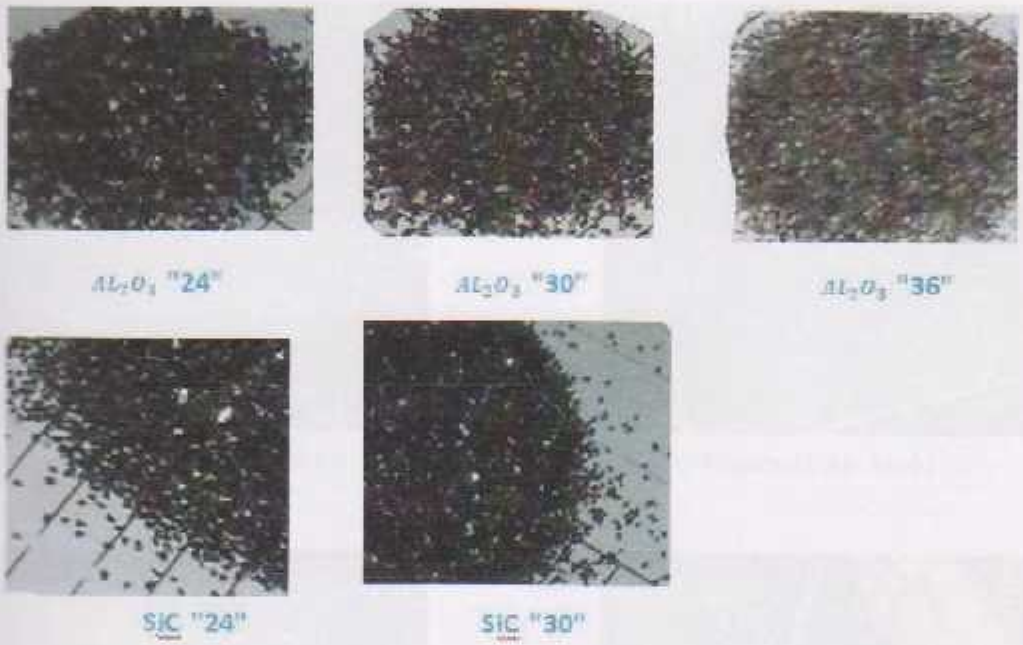


Figure (1.2): Raw materials of disc with number of grains

Figure (1.3): Containers Of Materials

Figure (1.4): Bonds

Figure (1.5): Mixture

Figure (1.6): Mold

Figure (1.7): Disc after pressed

Figure (1.8): Balancing machine

Figure (1.9): Weighting

Figure (1.10): Furnace

1.2.2 Classification of discs in Jelanco factory

Jelanco factory produce many types of discs depends on the industrial applications such as grinding and cutting operations, so they produce several discs with varying in shape and diameter as shown in Table (1.2),where (A) means Aluminum oxide and C means Silicon carbide.

Table (1.2): classification off discs

Abrasive type	Diameter (in)	Thickness (in)	Bore (in)	Total mass (g)	Speed (rpm)	unbalance mass(g) Allowable	Type of disc
A	4	1/8	5/8	54 ± 3	15300	m < 2	Cup E27
C	4	1/8	5/8	57 ± 3	15300		
A	4	1/4	5/8	114 ± 3	15300		
A	4.5	1/8	7/8	80 ± 3	13300		
A	4.5	1/4	7/8	160 ± 3	13300		
C	4.5	1/8	7/8	70 ± 3	13300		
A	7	1/8	7/8	180 ± 6	8750	m < 3	
A	7	1/4	7/8	370± 6	8750		
C	7	1/8	7/8	160± 6	8750		
C	7	1/4	7/8	335 ± 6	8750		
A	7	5/16	7/8	460± 6	8750		
A	9	1/8	7/8	285 ± 10	6800		
C	9	1/8	7/8	255 ± 10	6800		
A	9	1/4	7/8	575 ± 10	6800		
C	9	1/4	7/8	525 ± 10	6800		
A	12	5/32	7/8	700± 25	5100	m < 5	Flat
A	14	5/32	7/8	880± 25	4400		
A	16	5/32	1	1200± 25	3700		

1.2.3 Traditional Balancing Test in Jelanco Factory

After manufacturing discs, all discs must be tested through three important tests called balance test, speeder test and testing under operation,to obtain the final product that is ready to be used.

The first one is called balance test, this test will show if the distribution of the mass over the disc is uniform, this done by the following mechanism, this mechanism consist of four bearings, two bearings on each side, and a shaft that will roll over them as shown in Figure (1.11), the shaft is free to rotate, knowing that two forces will effect the shaft, the first one is the weight of disk, the second is an initial force given from the person that will perform the test.

The disc will be fixed on the shaft, the shaft starts to rotate under the two force mentioned before, but if the disc rotates and stops on position A " down direction", this means that an unbalance mass exists in direction of position A, so the disc is said to be unbalanced, on other hand if the disc does not stops on any position, this means that the disc is free to rotate, so the mass of the disc is distributed uniformly and the disc pass the balance test and real to used.

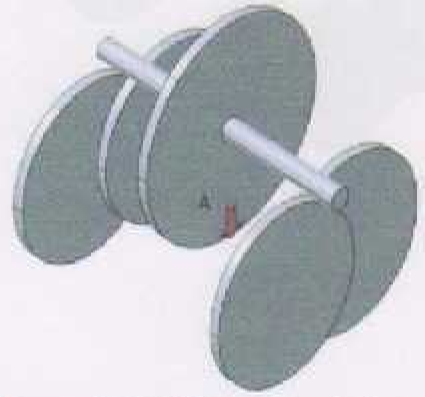


Figure (1.11): Disc with unbalance mass

To inspect the unbalanced discs, a known mass is added on the surface of the disc depend on trial and error method , as an example select disc from table (1.2) to explain the process.

C	9	255 ± 10	m < 3

Unbalance mass here is determined and localized by attaching a 3g mass in the opposite direction of A" up direction "as show in Figure (1.12) on a distance of D/2,then perform the unbalance test again, note that before and after every balance operation, the disc must be weighted on electronic Libra, and balance test has to be applied on every disc.

The traditional test that described has many disadvantages such as slow, not accurate, has large human error and uses two devices to complete the test.

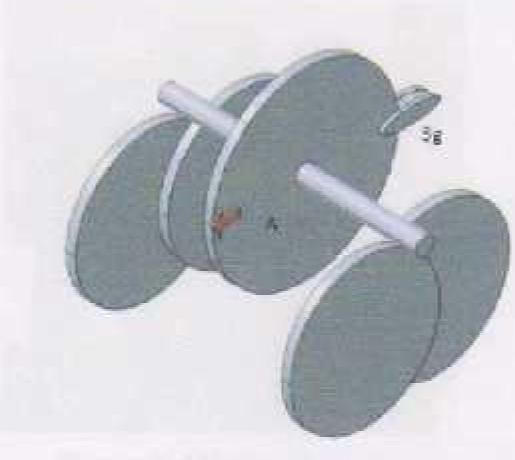


Figure (1.12): Balancing test

Therefore, this project aims to design a precise and electronic measurement system to test the unbalance in the disc and to determine the magnitude and location of the unbalancein the discs and to measure the total weight of the disc in the same time, with reduction of test time and increase accurate and efficiency.

The second test is called " speeder test" used to test stiffness of disc this machine gradually increases rotation speed of the disc until explosive the disc and note the speed and compare the number with rated speed of disc, if explosive speed more than rated this is pointed to stiffness of disc, here is taken as a sample from one thousand discs or more, shown in figure(1.13)

Third test use to determine how much meters the disc will operate during cutting operation. This test manually and is taken sample from one thousand or more.[1]

Figure (1.13): Speeder test

1.3 Definition of static balance and dynamic balance.

Static balance: is the condition when the center of gravity of the rotor system lies on the axis of rotation.

Dynamic balance: is the condition when the rotor system is in static balance and when in addition the centrifugal forces of the rotor system have zero resultant moment about any axis perpendicular to that of rotation.

Static unbalance force: is the component of unbalance which can be corrected by statically methods, namely by adding a single balance weight in a plane passing through the center of gravity of the rotor system and perpendicular to that of rotation. When corrected by dynamical methods using to balancing planes, the balance weights must be added at the same angular positions, and their magnitudes must be such that their centrifugal forces have zero resultant moment about an axis through the center of gravity and perpendicular to that of rotation.

Dynamic unbalance moment: is the component of unbalance which can be corrected only by dynamical methods. Two balance .Weight are always required and these must be added in separate planes with their angular positions diametrically opposite each other .The magnitudes of the weights must be such that their resultant centrifugal force is zero :in other words if they are placed at a common distance from the axis of rotation ,the weights must have equal magnitude.[4]

1.4 Static balance testing in Jelanco.

Balance testing in Jelanco Factory is static balance test, because it is:

1. Simple and easy for design and implementation.

2. Static balance does the same function as dynamic balance because the disc is planer
3. No need for high power and special sensor not available for the dynamic method.

So for this reason this method was considered in designing the new balance testing machine.

1.5 Time Table

Time tables (work are plane) very important for success of any project in our life.

This project needs two semesters to complete it, so each task must be performed on best side.

The First Semester:

Table (1.3): Time Table of First Semester

	Time (week)															
Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Selection the project																
Search about information																
Introduction and background																
Modeling and mechanical design																
Control design																
Evaluation and review																
Writing																
final edition																

The Second Semester:

Table (1.4): Time Table of Second Semester

	Time (week)															
Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Implementation of mechanical design																
Testing and experimentation																
Result and conclusion																
Evaluation and review																
Writing																
final edition of project																

Chapter Two

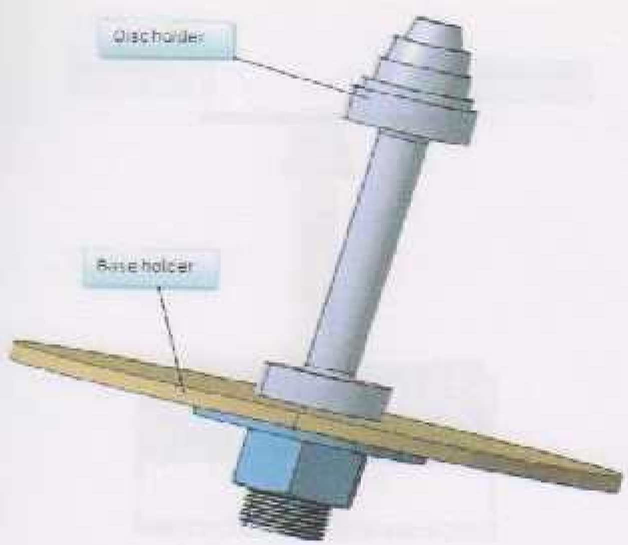
Mathematical modeling and analysis

Theory

Mathematical model

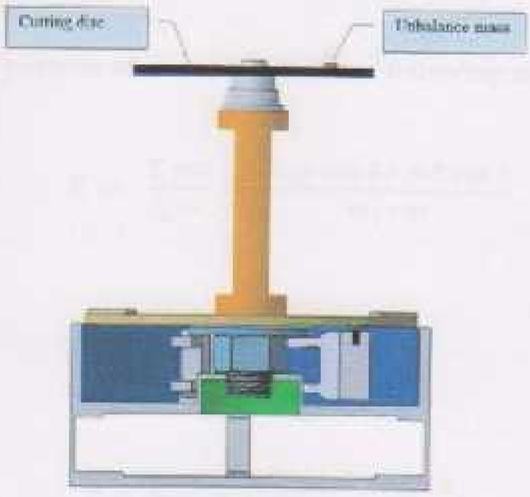
Design *r* parameter

Effect unbalance mass on the worker hands



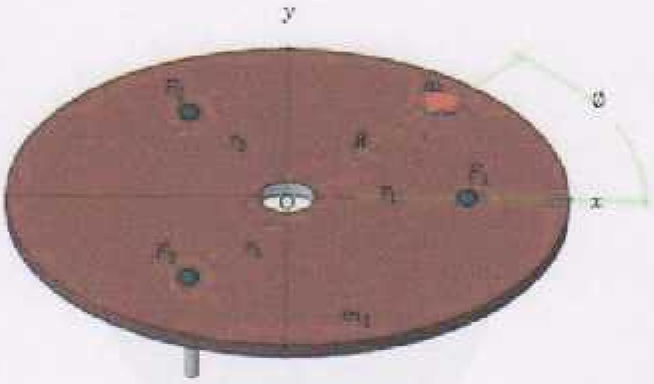
Figure(2.2): disc holder with base.

On the top of the shaft the disc will be fixed as shown in Figure(2.3),the load cells will measure the weight, if the three load cells have the same output reading that's mean disc balance, if not that's mean unbalance disc, the difference in the measurements of the cells will be entered in equations to determine unbalance mass specifications as will be discussed through this chapter.



Figure(2.3): disc under test.

As shown in Figure (2.4) F_1,F_2 andF_3 represent load cells distributed by constant angel (120°). Assume m is the unbalance mass in the disc, the unbalance mass will effect on the load cells and make difference in output signals, also it makes shift on center of gravity of the disc as shown Figure(2.5) from the origin point O (0,0) to the point $\bar{O}(\bar{x},\bar{y})$.



Figure(2.4): Disc with unbalance

To calculate the new position of center of gravity as following equations:

$$\bar{x} = \frac{\sum mx}{\sum m} = \frac{m_1 x \cos\emptyset + mR\cos\emptyset}{m_1 + m} \tag{2-1}$$

Since, $x = 0$

$$\bar{x} = \frac{mR\cos\emptyset}{m_1 + m} \tag{2-2}$$

$$\bar{y} = \frac{\sum my}{\sum m} = \frac{m_1 y \sin\emptyset + mR\sin\emptyset}{m_1 + m} \tag{2-3}$$

Since, $y = 0$

$$\bar{y} = \frac{mR\sin\emptyset}{m_1 + m} \tag{2-4}$$

The total mass of disc:

$$M = m_1 + m \tag{2-5}$$

Square (2.2) and (2.4) to obtained polar form

$$e = \frac{mR}{M} \tag{2-6}$$

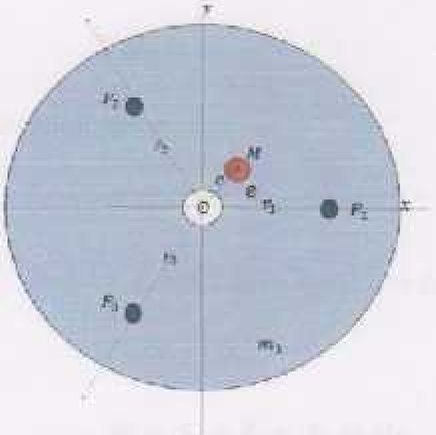


Figure (2.5): Disc with new center of gravity-top view where,

m_1 : mass of Disc without (m).

Max. Unbalance radius (R): distance between center of Disc and center of unbalance mass.

θ: angel between positive x-axis and center of unbalance mass.

$r_1, r_2 and r_3 = r$

r: distance between center of disc and load cell.

$eccentricity(e)$: the displacement value caused by unbalance mass that represent the distance between O and $\bar{O}$.

2.2 Mathematical model

The conditions of equilibrium of a rigid body subjected to a three dimensional force system require that both the resultant force and resultant couple moment acting on the body be equal to zero as shown in Figure (2.4)

Vector equation of equilibrium

$$\sum F = 0 \tag{2-7}$$

$$\sum M_O = 0 \tag{2-8}$$

Summing force in the Z direction yields

$$\sum F_Z = 0 \tag{2-9}$$

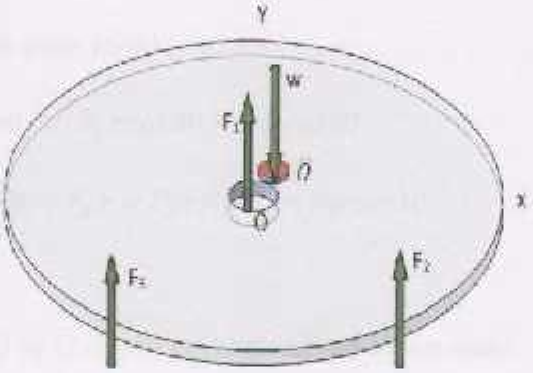
$$F_1\hat{k} + F_2\hat{k} + F_3\hat{k} - W\hat{k} = 0 \tag{2-10}$$

Where,

$$W = F_1 + F_2 + F_3 = Mg \tag{2-11}$$

Then, to get total mass as :

$$M = \frac{F_1 + F_2 + F_3}{g} \tag{2-12}$$



Figure(2.6):Free Body Diagram

Moment summation necessary to determine unbalance mass and angle of unbalance mass, refer to free body diagram, Figure(2.6)and Figure (2.5) to analysis equations as following:

$$\sum M_O = 0 \tag{2-13}$$

By vector form:

$$e \times Mg = r_1 \times F_1 + r_2 \times F_2 + r_3 \times F_3 \tag{2-14}$$

$$e(cos\emptyset\hat{\imath} + sin\emptyset\hat{\jmath}) \times Mg\hat{k} = r_1\,\hat{\imath} \times F_1\,\hat{k} + r_2(cos30\hat{\jmath} - sin30\hat{\imath}) \times F_2\,\hat{k} + r_3\,(-cos30\hat{\jmath} - sin30\,\hat{\imath}) \times F_3\hat{k} \tag{2-15}$$

Note : $r_1 = r_2 = r_3 = r$

After substitute r in (2-16) to get:

$$-Mgecos\emptyset\hat{\jmath} + Mgesin\theta\hat{\imath} = -F_1\,r\hat{\jmath} + F_2\,rcos30\hat{\imath} + F_2\,rsin30\hat{\jmath} - F_3rcos30\hat{\imath} + F_3rsin30\,\hat{\jmath} \tag{2-16}$$

Separated equation (2-16) to obtained two equation of moment in two direction:

$$Mgesin\emptyset\hat{i} = F_2 rcos30\hat{i} - F_3 rcos30\hat{i} \quad (2\text{-}17)$$

$$-Mgecos\emptyset\hat{j} = -F_1 r\hat{j} + F_2 rsin30\hat{j} + F_3 rsin30\,\hat{j} \quad (2\text{-}18)$$

Rewrite up equations in other form:

$$Mgesin\emptyset = F_2 rcos30 - F_3 rcos30 \quad (2\text{-}19)$$

$$Mgecos\emptyset = F_1 r - F_2 rsin30 - F_3 rsin30 \quad (2\text{-}20)$$

Divide equation (2-19) by (2-20) to get angle of unbalance mass:

$$tan\emptyset = \frac{2cos30(F_2 - F_3)}{2\,F_1 - F_2 - F_3} \quad (2\text{-}21)$$

$$\emptyset = (\tan^{-1}\left[\frac{2cos30(F_2 - F_3)}{2\,F_1 - F_2 - F_3}\right]) * (180°/pi) \quad (2\text{-}22)$$

After determine the unbalance mass angle (∅), must be determine compensation angle, that will new mass compensate on it, as following:

$$\theta = \emptyset + 180° \quad (2\text{-}23)$$

θ : compensation angle to make disc is balancing .

By square Equation (2-19) and Equation (2-20) then sum the results

$$Me = \sqrt{\frac{r^2\,(F_1^2 + F_2^2 + F_3^2) - 2r^2\,[\,0.5F_1 F_2 + 0.5F_1 F_3 + 0.5F_2 F_3\,]}{g^2}} \quad (2\text{-}24)$$

$$Me = r\sqrt{\frac{(F_1^2 + F_2^2 + F_3^2) - (F_1 F_2 + F_1 F_3 + F_2 F_3\,)}{g^2}} \quad (2\text{-}25)$$

Also can rewrite equation (2-25) as:

$$mR = r\sqrt{\frac{(F_1^2 + F_2^2 + F_3^2) - (F_1 F_2 + F_1 F_3 + F_2 F_3)}{g^2}} \qquad (2\text{-}26)$$

Then, $mR \angle \emptyset$neutralization by$\bar{m}\bar{R}\angle\theta$ and make the disc is balanced, so to find new mass must be suppose distance$\bar{R}$, as following equation:

$$\bar{m} = \frac{mR}{\bar{R}} \qquad (2\text{-}27)$$

$\bar{m}$: new mass add to the disc to recognize balance test.

$\bar{R}$ = the distance that balancing mass put on it, and its equal $D/2$for each disc.

Finally, three equations are enough to decide the disc is balanced or not.

2.3 Design $r$parameter

To design a significant r it must be accommodate the following factors:

1. Resolution.
2. Accuracy.
3. Cost.
4. Size and shape apparatus .

Also can rewrite equation (2-25) as:

$$mR = r\sqrt{\frac{(F_1^2 + F_2^2 + F_3^2) - (F_1 F_2 + F_1 F_3 + F_2 F_3)}{g^2}} \qquad (2\text{-}26)$$

Then, $mR \angle \emptyset$ neutralization by $\bar{m}\bar{R}\angle\theta$ and make the disc is balanced, so to find new mass must be suppose distance $\bar{R}$, as following equation:

$$\bar{m} = \frac{mR}{\bar{R}} \qquad (2\text{-}27)$$

$\bar{m}$: new mass add to the disc to recognize balance test.

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Finally, three equations are enough to decide the disc is balanced or not.

2.3 Design r parameter

To design a significant r it must be accommodate the following factors:

1. Resolution.
2. Accuracy.
3. Cost.
4. Size and shape apparatus .

Resolution and accuracy are very important factor to select suitable r and can discuss it by refer to 2.12,20,21 equations and get:

$$F_1 = Mg - F_2 - F_3 \tag{2-28}$$

$$F_2 = \frac{mgRsin\emptyset}{rcos30} + F_3 \tag{2-29}$$

$$mgRcos\emptyset = F_1 r - F_2 rsin30 - F_3 rsin30 \tag{2-30}$$

$$\frac{mgRcos\emptyset}{r} = F_1 - 0.5F_2 - 0.5F_3 \tag{2-31}$$

By adding (2.28) , (2.29) and (2.31) the result is :

$$F_3 = \frac{Mg}{3} - \frac{mgRcos\emptyset}{3r} - \frac{mgRsin\emptyset}{2rcos30} \tag{2-32}$$

Programming the last equations (2.29), (2.30) and (2.33) in MATLAB to study reaction or behavior the Load cells and affect of changing (r). Suppose a disc has diameter 9", 525g mass, and adding unbalance mass m=3g with angle 45°.

Two values of r , will discussed here:

1. $r = 5cm$
2. $r = 10cm$

When,r =5 cm

```
M=0.528;
m=0.003;
R=0.1143;
r=0.05;
g=10;
fi=(45*pi)/180;
F3=M*g/3 - (m*g*R*cos(fi))/(3*r) - (m*g*R*sin(fi))/(1.73*r)
F2=(m*g*R*sin(fi))/(0.866*r) + F3
F1= M*g - F2 -F3
W= (F1 + F2 +F3)/g
```

F_3 =1.7371 $\Delta F_3 = |Mg - F_3| = 0.0229$N

F_2 =1.7371 $\Delta F_2 = |Mg - F_2|$ =0.0229N

F_1 =1.8057 $\Delta F_1 = |Mg - F_1|$ =0.0457N

M = 0.5280/3 = 176g

When,r =10 cm

```
M=0.528;
m=0.003;
R=0.1143;
r=0.1;
g=10;
fi=(0*pi)/180;
F3=M*g/3 - (m*g*R*cos(fi))/(3*r) - (m*g*R*sin(fi))/(1.73*r)
F2=(m*g*R*sin(fi))/(0.866*r) + F3
F1= M*g - F2 -F3
W= (F1 + F2 +F3)/g
```

F_3 =1.7486 $\Delta F_3 = |Mg - F_3|$ =0.011N

F_2 =1.7486 $\Delta F_2 = |Mg - F_2|$ =0.011N

F_1 = 1.7829 $\Delta F_1 = |Mg - F_1|$ =0.0229N

M =0.5280/3 =176g.

From the previous calculations conclude these results:

1. Increasing r means increasing in the cost " load cell or sensor with high resolution needed"
2. Increasing r means increasing in the size of apparatus.

2.4 Effect unbalance mass on the worker hands

The main object of this section is study the effect of centrifugal force that is caused by the unbalance mass exist in the wheel before cutting or grinding operations.

To study and analysis effect of reactions forces from cutting and grinding machine must select a sample from discs optimized with machine, see Figure (2.7) and Table (2.1) to know characteristics of the machine.

C	9	525 ± 10	6800	m < 3

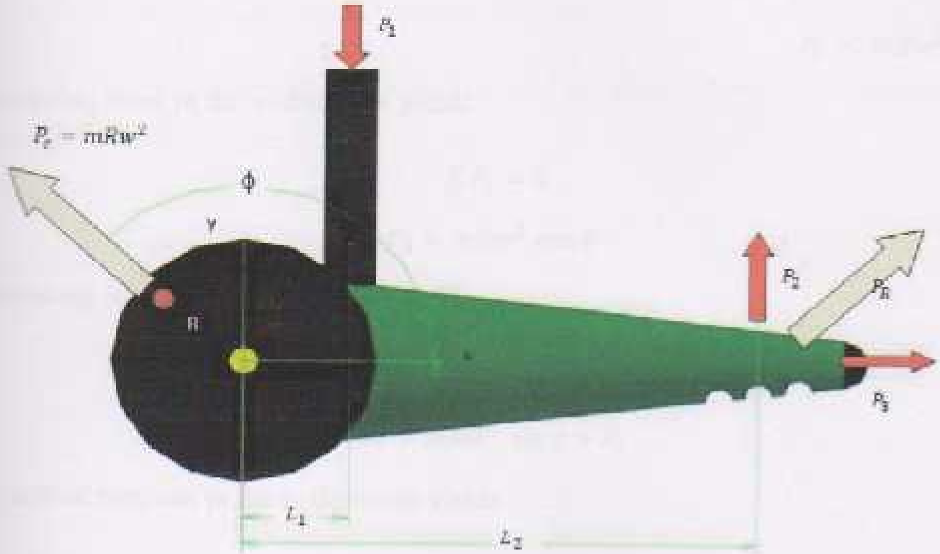


Figure (2.7): cutting and grinding machine

Table(2.1): characteristics of grinding and cutting-off machine

Diameter of Discs (in)	Max. Unbalance radius (R) (cm)	Angular Speed of machine (rpm)	Angular Speed of machine (rad)	L_1 (cm)	L_2 (cm)
4	5.08	11000	1152	2.5	20
4.5	5.715	11000	1152	2.5	20
7	8.89	6500	680.68	6	36
9	11.43	6500*	680.68	6	36
12	15.24	5000	523.6	6	36
14	17.78	4300	450.3	6	36
16	20.3	3800	398	6	36

By applying static equilibrium equations on the cutting machine we will obtain on:

$$P_c = mRw^2 \quad (2\text{-}33)$$

Summing force in the x- direction yields

$$\sum P_x = 0 \quad (2\text{-}34)$$

$$P_3 = mRw^2 \cos \emptyset \quad (2\text{-}35)$$

Summing force in the y- direction yields

$$\sum P_y = 0 \quad (2\text{-}36)$$

$$P_1 = mRw^2 \sin \emptyset + P_2 \quad (2\text{-}37)$$

Resultant moment in the z- direction yields

$$\sum M_z = 0 \quad (2\text{-}38)$$

$$P_1 L_1 = P_2 L_2 \quad (2\text{-}39)$$

$$P_2 = \frac{P_1 L_1}{L_2} \quad (2\text{-}40)$$

Then,

$$P_R = \sqrt{{P_2}^2 + {P_3}^2} \quad (2\text{-}41)$$

* In 9" disc the speed operation wobble between 6000 and 6500 rpm.

Where,

Max. Unbalance radius (R):distance between center of Disc and center of unbalance mass, it is be max. when equal radius of disc.

$P_1 and P_R$:represent max. reaction forces on worker hand caused by unbalance mass.

P_c: centrifugal force.

L_1 and L_2 distance between reaction forces and center of rotation shaft.

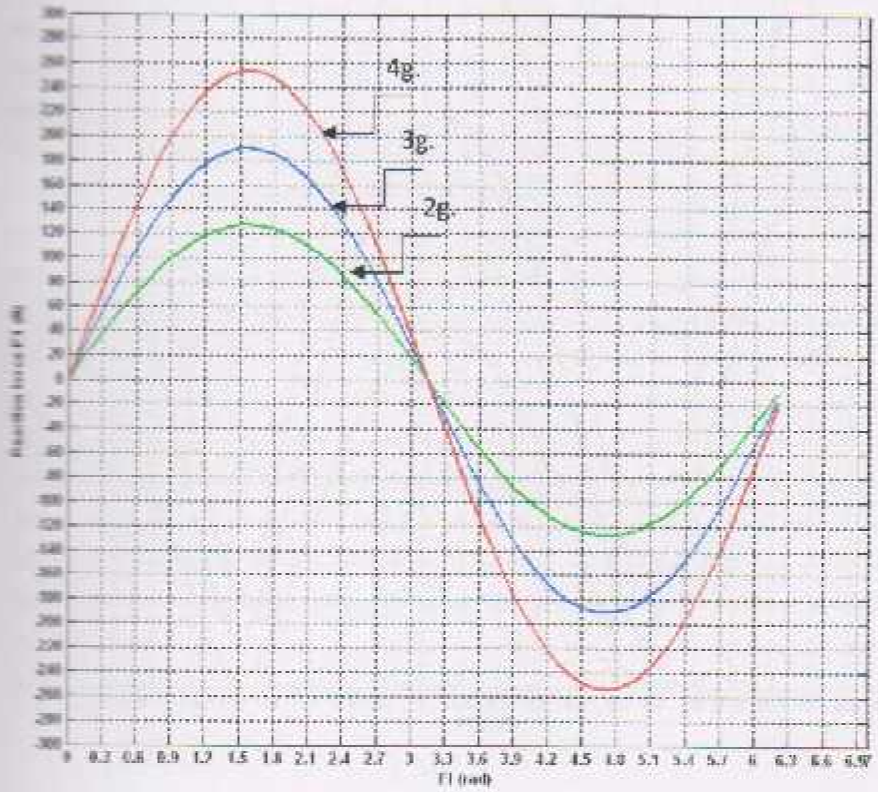
w: The average angular velocity of cutting and grinding machine.

ϕ : angel between positive x-axis and center of unbalance mass , their measure at max. reactions, The angle range between [0 - 360]

Here is a MATLAB program used to compute the forces acting on the worker hand due to the presence of unbalance.

```
m=0.003;
R=0.1143;
w=680.68;
fi=[0:0.1:2*pi];
L1=0.06;
L2=0.36;
P3=m*R*(w^2)*cos(fi);
P2=(m*R*(w^2)*sin(fi))/((L2/L1)-1);
P1=(P2*L2)/L1;
PR=((P2).^2 + (P3).^2).^0.5;
C1 = max(P1)
CR = max(PR)
plot(fi,P1)
hold on
plot(fi,PR)
```

See figures [2.5 ,2.6] to know the effect of change unbalance mass value between [2,3,4 g] with constant another parameters.



Figure(2.8): Relation between P_1 and angle ($\emptyset$)

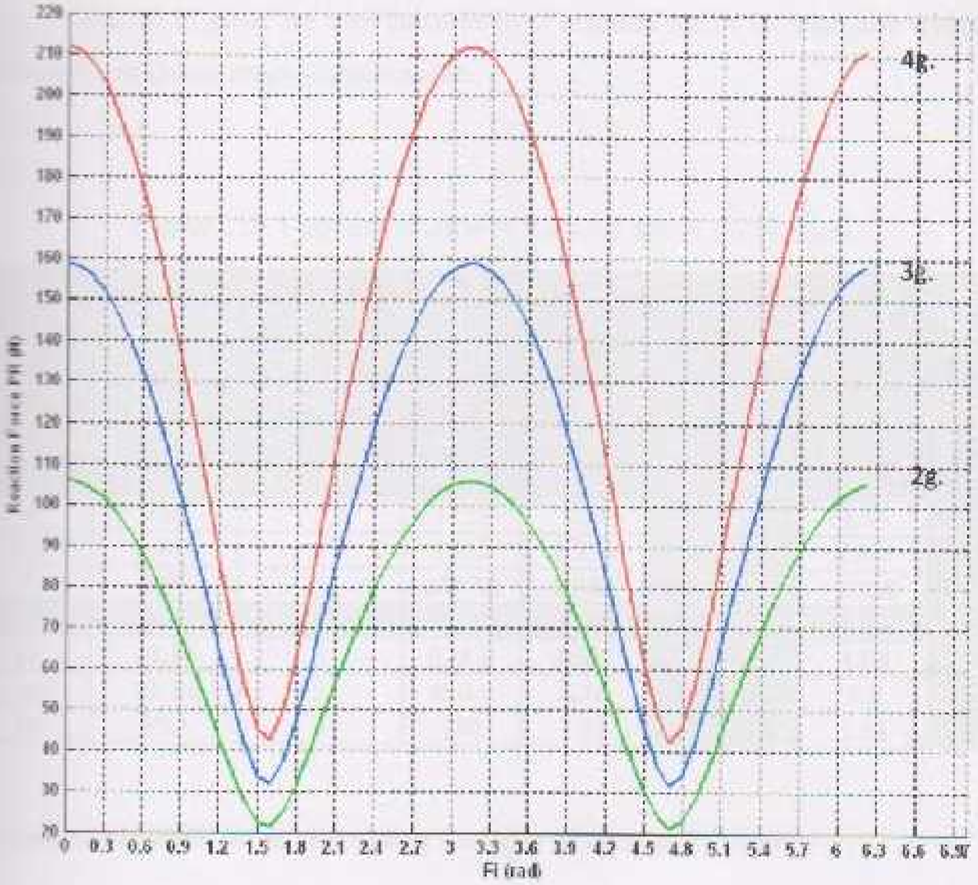
When,

m= 4g., the Max. Reaction Force (P_1) is 254.1N

m= 3g. , the Max. Reaction Force (P_1) is 190.5678N

m=2g., the Max. Reaction Force (P_1) is 127N

all of them give max. values at $\emptyset = \frac{(2n+1)\pi}{2}$,when $n = 0, \pm1, \pm2$ ....



Figure(2.9): Relation between P_R and angle ($\emptyset$)

When,

m= 4g., theMax. Reaction Force (P_R) is 211.83N

m= 3g., the Max. Reaction Force (P_R) is 158.8742N

m=2g., the Max. Reaction Force (P_R) is 105.9N

all of them give max. values at $\emptyset = \frac{n\pi}{2}$,when $n = 0, \pm1, \pm2$ ....

Table (2.2) gives the final calculation of reaction forces for each disc with the minimum unbalance mass – unallowable.

Table(2.2): Final calculation of reaction forces for all discs

Diameter of Disc (in)	Max. Unbalance radius (R) × 10^{-2}(m)	Minimum unbalance of masses(m) unallowable × 10^{-3} (Kg)	Max. Angular speed (w) (rad./s)	P_1 Reaction Force × 10^2 (N)	ϕ (rad.) With P_1	P_R Reaction Force × 10^2 (N)	ϕ (rad.) With P_R
4	5.08	2	1152	1.54	$\frac{(2n+1)\pi}{2}$	1.35	
4.5	5.715	2	1152	1.733		1.517	
7	8.89	3	680.68	1.482		1.236	
9	11.43	3	680.68	1.906		1.59	
12	15.24	5	523.6	2.506		2.09	
14	17.78	5	450.3	2.16		1.8	
16	20.3	5	398	1.93		1.61	

To understand table, let us discussing a sample of discs as following:

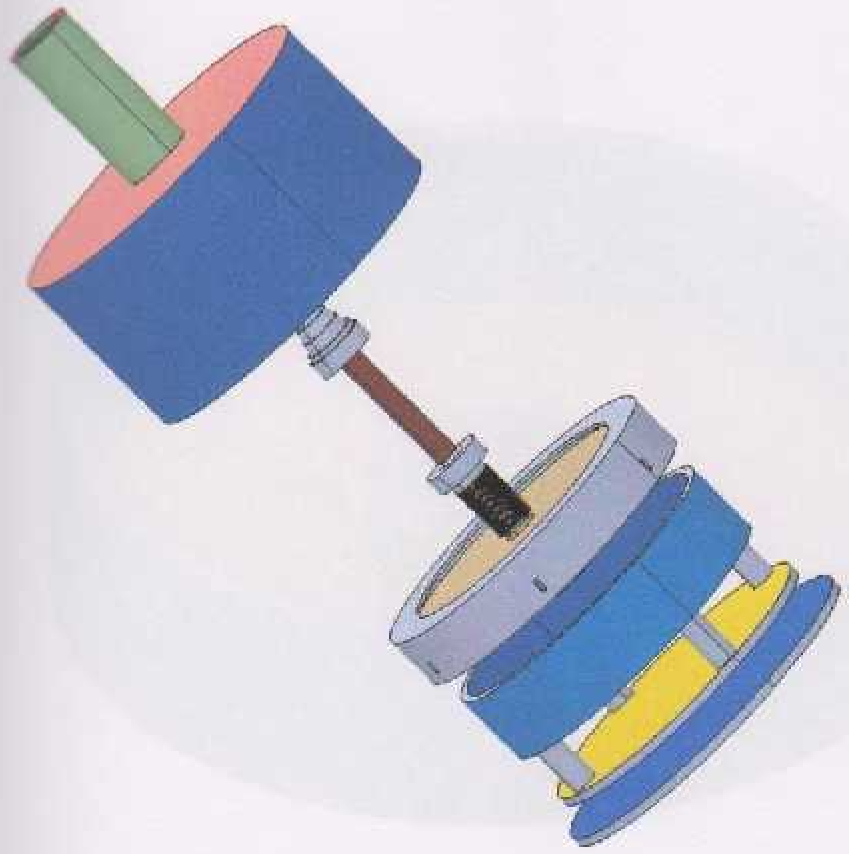
Disc has Diameter 9 inch(22.86 cm) with minimum unbalance mass – unallowable is 3 gram on distance 11.43 cm and rotate under 680.68 rad/s, so the result $P_1 = 190.6$ N or that's mean 19.06 kg affect on worker hand at 90° and 270° in complete cycle vertically, another hand 15.9kg effect on worker hand every 90°

Chapter Three

Geometric Design

The geometrical or structural design of the system is designed by CATIA program , that consist of the following parts: load cells container, discs holder, base holder of discs, calibration piece, container holder, electronic base, stand of load cells, mechanical joint, the cover and the base.

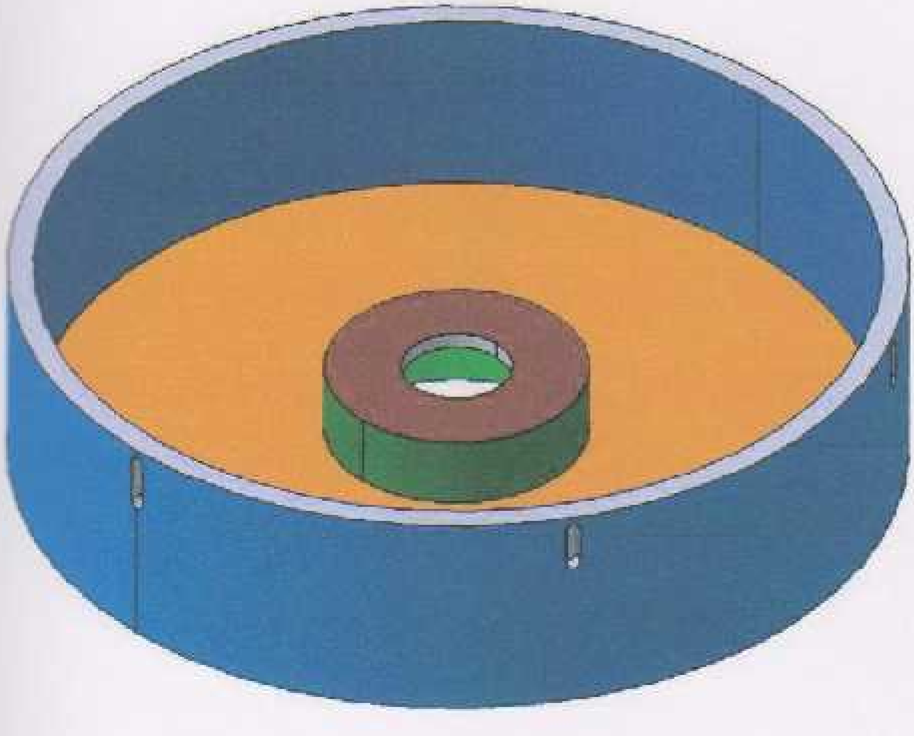
All the parts were mentioned before are assembled as shown Figure(3.1)



Figure(3.1): parts of system

1. Load cells container

A shell-shaped on the inside will contain three pieces of load cells, where these pieces will provide readings for the balance, also it contains the shell with a hole to provide protection for the disc holder, at the same time it contains six holes spread over the perimeter of the container by constant angles to construct a calibration part. See figure (3.2).



Figure(3.2): load cells container

The dimention and details for all mechanical part are expressed in Appendix (A).

2. Discs holder:

A cylinder-shaped bar to an end threaded and the other containing three different diameters depend on the diameter a bore of disc. See figure (3.3)

Figure(3.3): Discs holder

3. Base holder of Discs:

Their goal is to provide communication between the discs and load cells, "like the legs" and so that it can measure the weight of the discs and determine the amount of unbalance in the discs. See Figure (3.4)

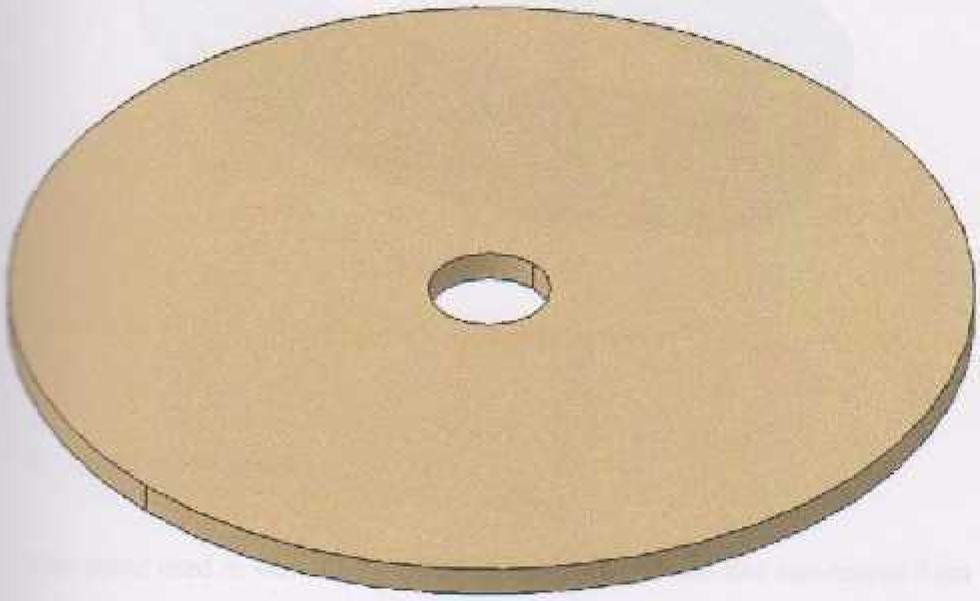
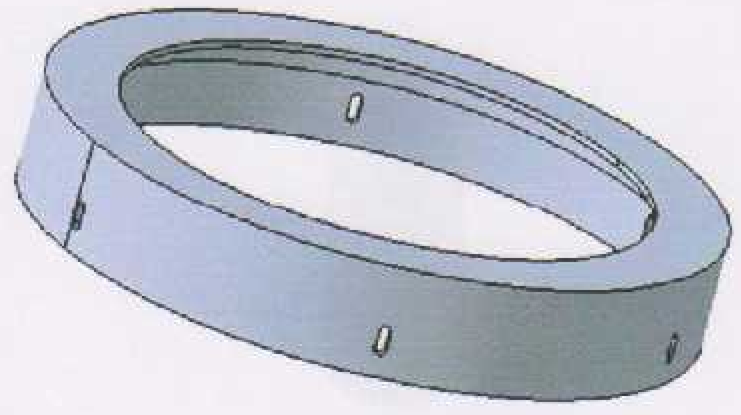


Figure (3.4): Base holder of Discs

4. Calibration part:

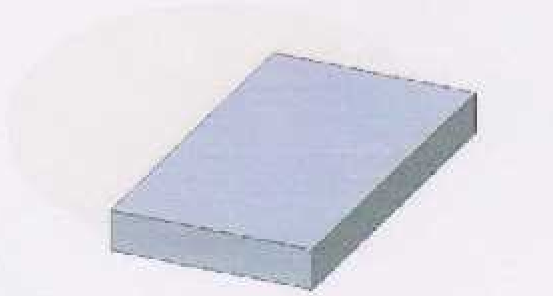
Apart is placed on the perimeter of the container as previously reported to be calibrated to prevent the base out of place under any circumstances. See figure(3.5).



Figure(3.5): Calibration part

5. Stand of load cells:

The stand used in work a level of the load cell, to obtain free movement from side the measurement . see figure(3.6)



Figure(3.6): Stand of load cell

6. Container holder:

This piece used to carry the container, and also a link between the container and the electronic base. See figure(3.7).

Figure(3.7): Container holder

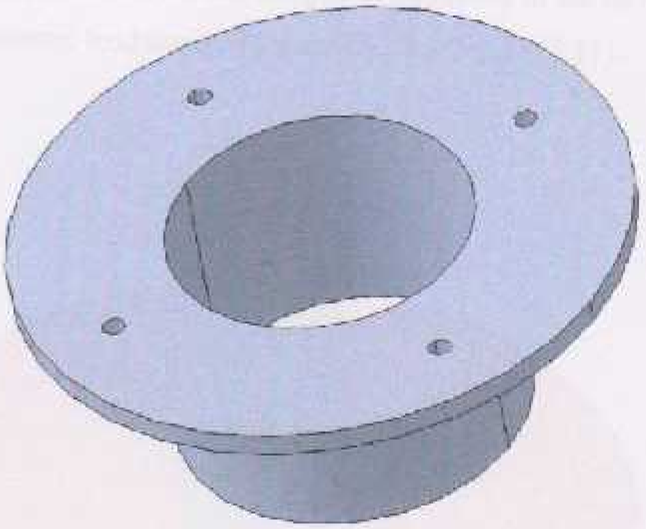
7. Electronic base:

Used to construct the electronic circuits on it. See figure(3.8).

Figure(3.8): Electronic base

8. Flange

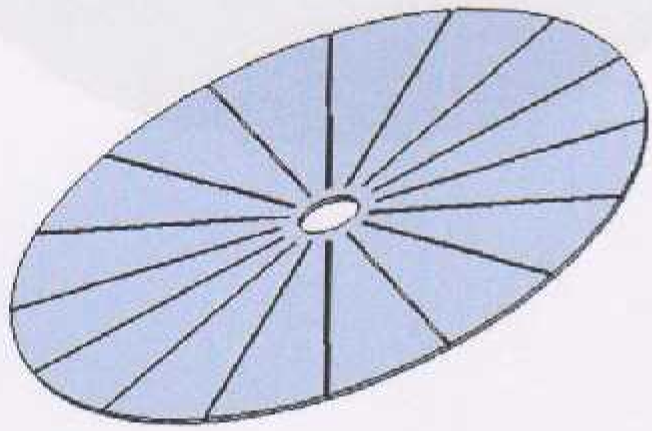
Used for carry the angular and fixed it with the cylinder that save the shaft, and to fixed this cylinder with the lower part of the cover.



Figure(3.9): Flange

9. Angular

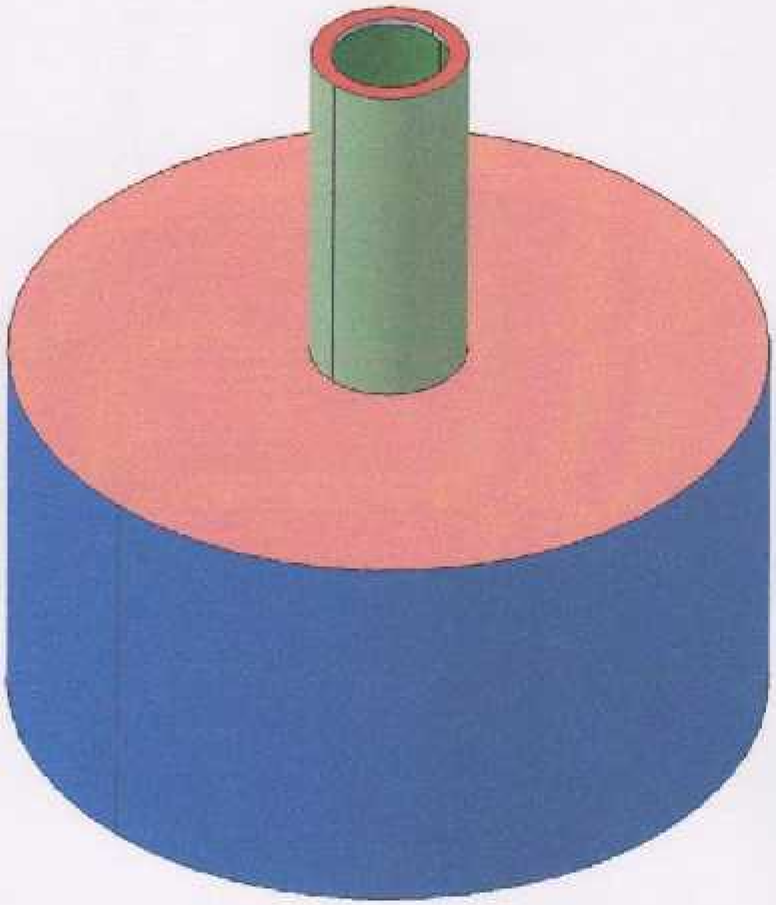
Used to locating the angle where the mass muss be compensated to make the disc balanced.



Figure(3.10): The angular

10. The cover:

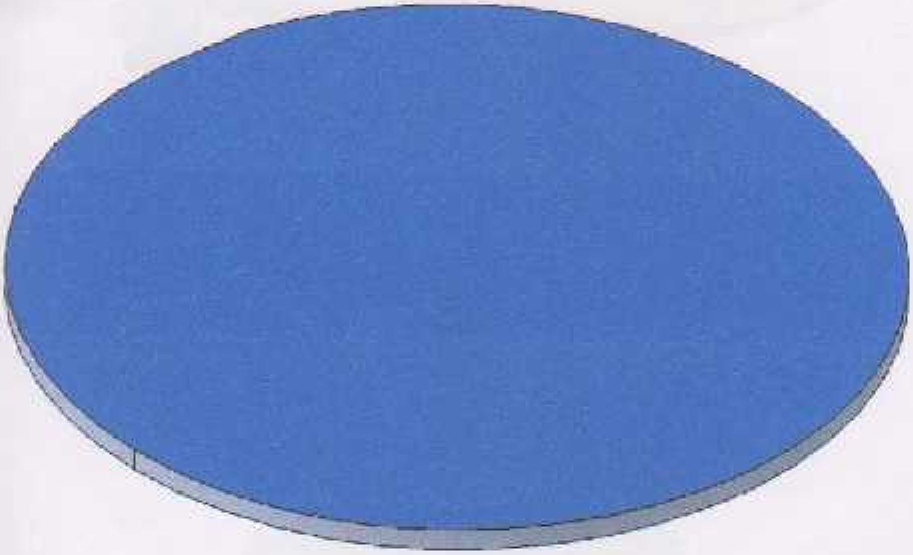
It provides full protection for the internal components of the device in addition to giving aesthetic landscape of the device. See figure (3.11).



Figure(3.11): The cover

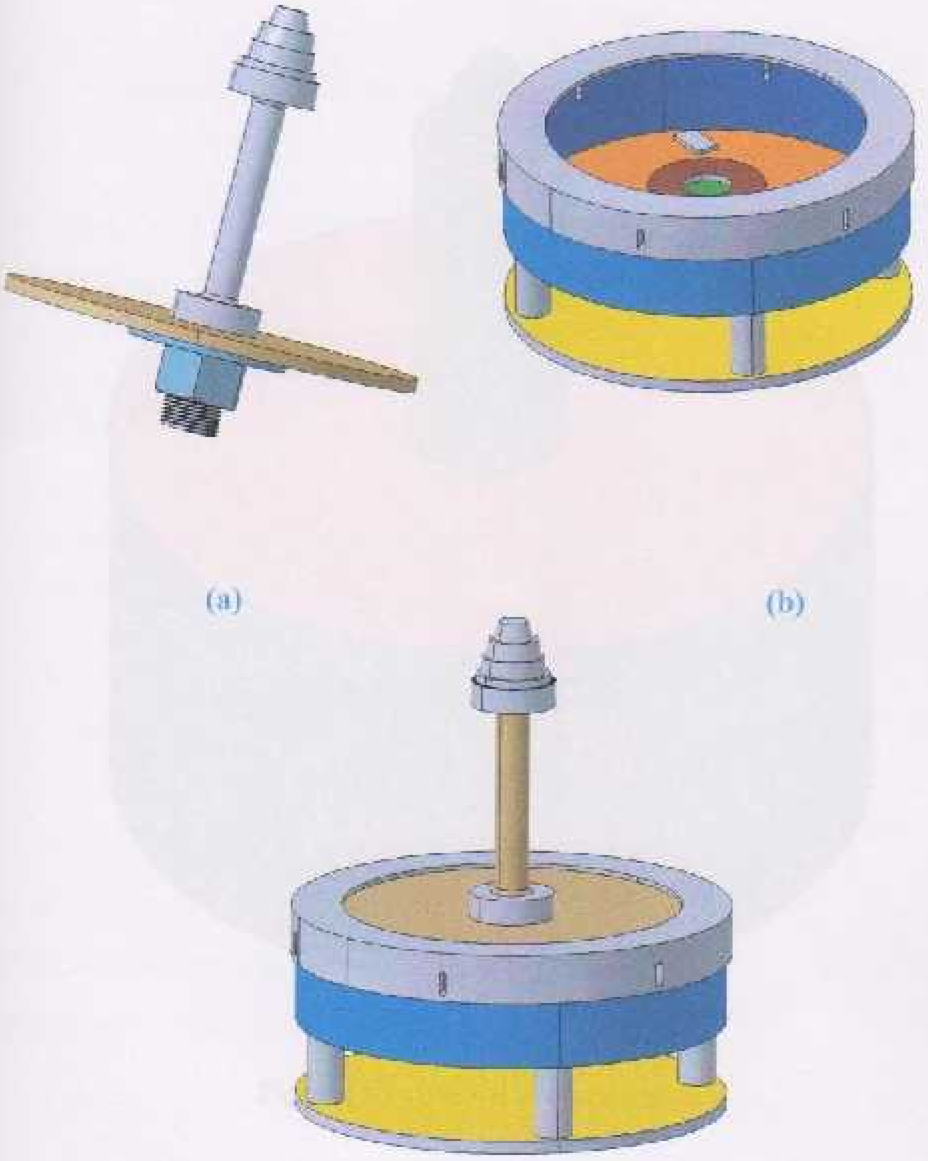
11. The base

Working to close the cover. See Figure (3.12)



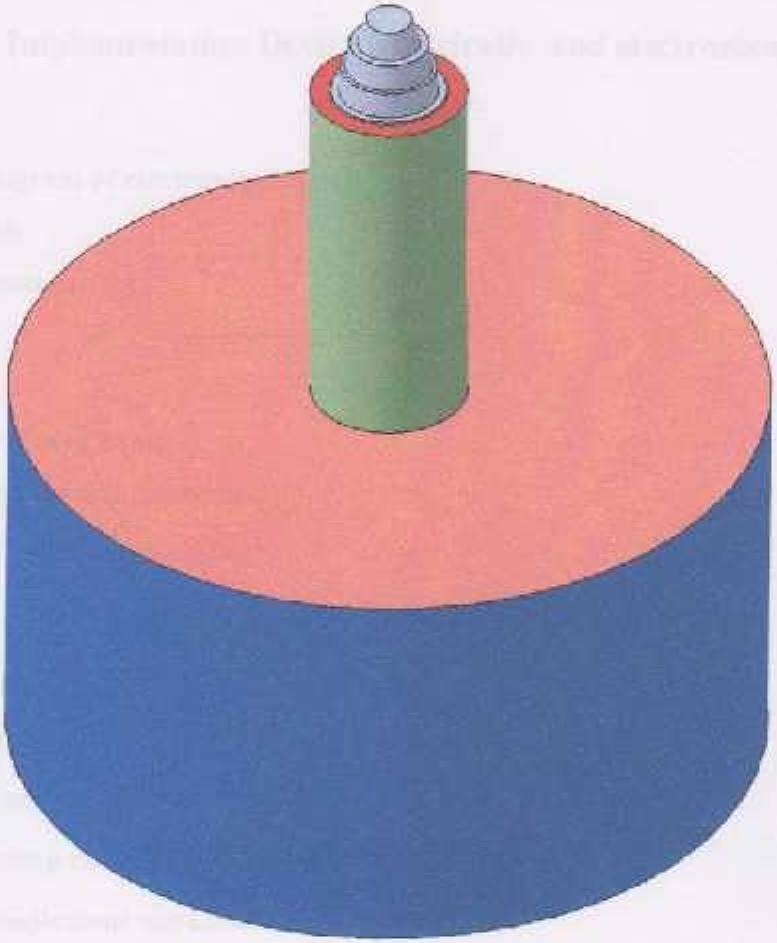
Figure(3.12): The base

The following figure (3.13) is pictures of the parts that assembled



Figure(3.13): Internal parts of a device construct from (a)&(b)

The final form of apparatus as shown in Figure (3.14)



Figure(3.14): Final form of a device

Chapter Four

Implementation Device electrically and electronically

Block diagram of electronic design

Load cells

Implementation by

Part A:

DAQ

Amplification circuit

AD 620 instrumentation amplifier

Labview software

Part B:

PIC- Microcontroller

How to select PIC- Microcontroller

PIC pin out

Conditioning circuit "amplification and filtration"

How to implement mathematical model

Hardware connection for all parts

4.1 Block diagram of electronic design:

Most of the devices, that are manufactured or those that exist between our hands are composed of two main parts: first, construct mechanical and structural parts , the other is construct electronic and electrical parts.

In the last chapter a detailed mechanical design of the system has been developed, this chapter will discuss the electronic design that achieves the required system in terms of measurement and readings.

The functional block diagram of the measuring method used in this project is shown in Figures (4.1), (4.2):

Figure (4.1): DAQ method

Figure (4.2): PIC method

4.2 Load cells

Before expressing the electronic circuits and electrical implementation of the project, the most important characteristics of load cells that have been discussed through the selection of load cells as following

The most important characteristics of load cells:

1. The impact points: for example, single point, double ended, central ... etc.
2. Capacity: 0.5 kg, 5 kg, 50 kg........ etc.
3. Precision and resolution.
4. Cost.
5. Total error better than 0.0067% of rated output.

Therefore the selection of load cell as shown in figure (4.3) is a single point load cell – Model 1004 with capacity 1.5Kg for each, and 0.05 g resolution since the highest mass of disc is 1.2Kg in Jelanco factory as shown in chapter one in table (1.1)[5] .

Figure (4.3): load cell Model 1004

Appendix B.1 shows more characteristics of this load cell.

4. 3 DAQs:

4.3.1 Introduction

PC-based data acquisition uses a combination of modular hardware, application software, and a computer to take measurements. While each data acquisition system is defined by its application requirements, every system shares a common goal of acquiring, analyzing, and presenting information. Data acquisition systems incorporate signals, sensors, actuators, signal conditioning, data acquisition devices, and application software and gathering signals from measurement sources and digitizing the signal for storage, analysis, and presentation on a PC as shown in figure(4.4)

Figure (4.4): DAQ system

Data acquisition (DAQ) systems come in many different PC technology forms for great flexibility when choosing the system. Scientists and engineers can choose from PCI, PXI, PCI Express, PXI Express, PCMCIA, USB, Wireless and Ethernet data acquisition for test, measurement, and automation applications .

Figure (4.5): Components needed to build DAQ system

There are five components to be considered when building a basic DAQ system shown as fig (4.5):

- Transducers and sensors
- Signals
- Signal conditioning
- DAQ hardware
- Driver and application software[6]

4.3.2 Amplification circuit

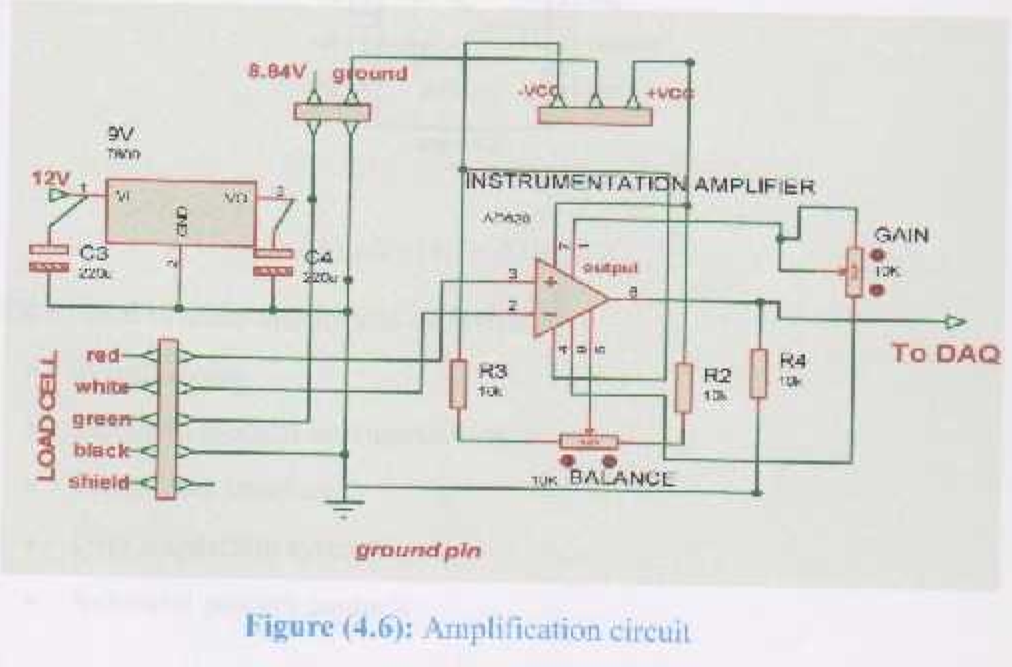


Figure (4.6): Amplification circuit

The signal resulted from the load cells is very small, so all signals must be amplified bythe instrumentation amplifier AD 620 as construct in the amplification circuitas shown in Figure (4.6). the noise of the signals will be processed through the filtration circuit insert the DAQ .

4.3.3AD 620 Instrumentation Amplifier

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gain, and has general specifications and features such that:

1. Easy to use
2. Gain set with one external resistor (Gain range 1 to 10,000)
3. Low noise 0.28 μV p-p noise (0.1 Hz to 10 Hz)
4. Excellent dc performance

Figure (4.7) shows general form of AD620 IC

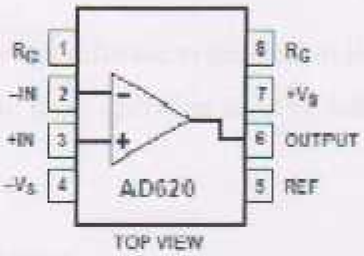


Figure (4.7): AD620 IC

AD620 used in many application such that:

- Weigh scales
- ECG and medical instrumentation
- Transducer interface
- Data acquisition systems
- Industrial process controls

4.3.4 Labview software

LABVIEW (Laboratory Virtual Instrumentation Engineering Workbench) is a platform and development environment software for a language in DAQ as shown in figure (4.8).

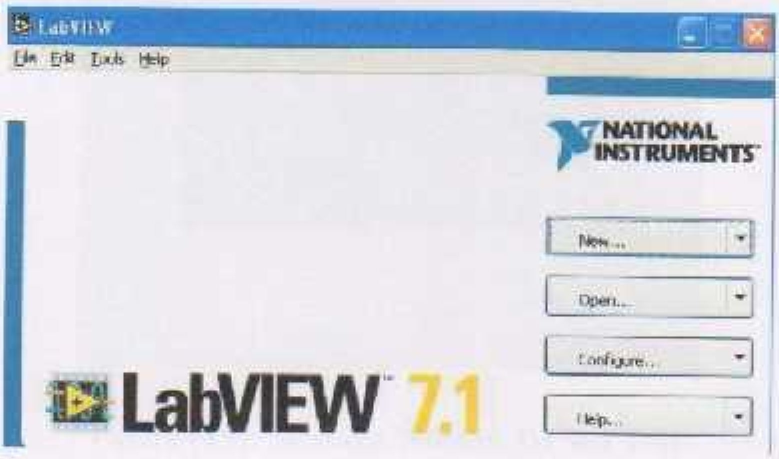


Figure (4.8): Labview look

DAQ using the Labview software to implement the operation and to show the connection of the circuits, all these operation must be follows in a sequence of steps:

4.3.4.1 Self-test of DAQ

The self-test option runs a brief test of device resources, and then presents a message window with the results of the test as shown in figure (4.9).

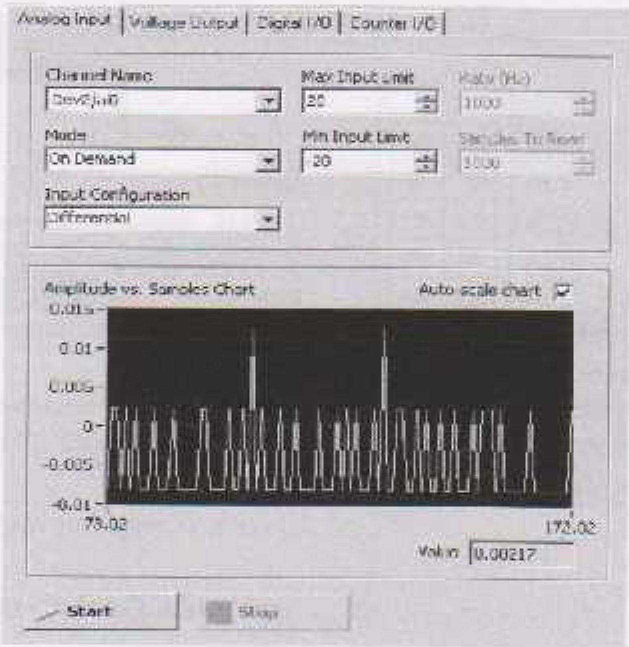


Figure (4.9): Message Window Of Self-Test

The Test Panels window is used for testing the analog input, analog output, digital I/O, and counter functionality of DAQ device, this is a great utility for troubleshooting because it allows you to test the functionality of your device directly from NI-DAQ. If your device doesn't work in the Test Panel, it isn't going to work in Labview. If you are ever having unexplainable trouble with data acquisition in a Labview program, you can use the self-test and the Test Panels to make sure the device is working properly.

4.3.4.2 Connection of terminals

Connect the input wires of the analog input voltage to the DAQ in the terminals as shown in the figure (4.10) below which is a part of whole terminals, not that AI 0 is referred to analog input with port number zero.

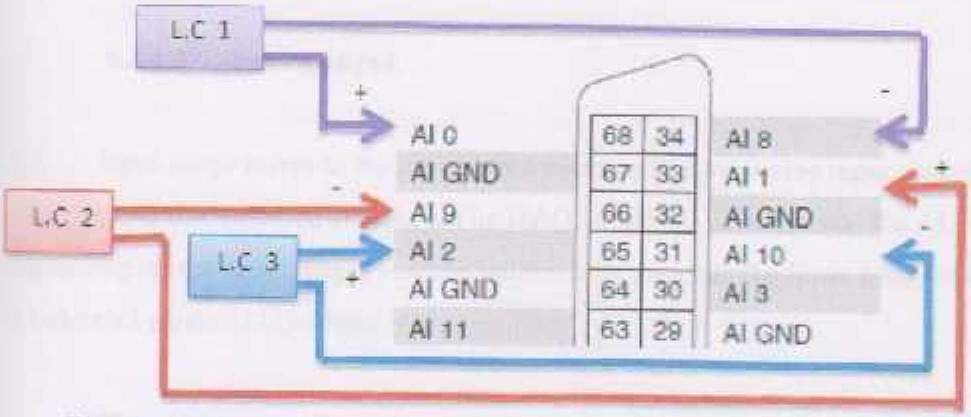


Figure (4.10): Load cell differential connection on screw terminal

See appendix to show full specification (B.2)

4.3.4.3 Create DAQ assistance

Before cover analog and digital I/O in depth, it's time to try acquiring data hands-on in Labview first, the DAQ Assistant is an express virtual instrument(VI) that creates, edits, and runs tasks using NI-DAQ as shown in figure (4.11)

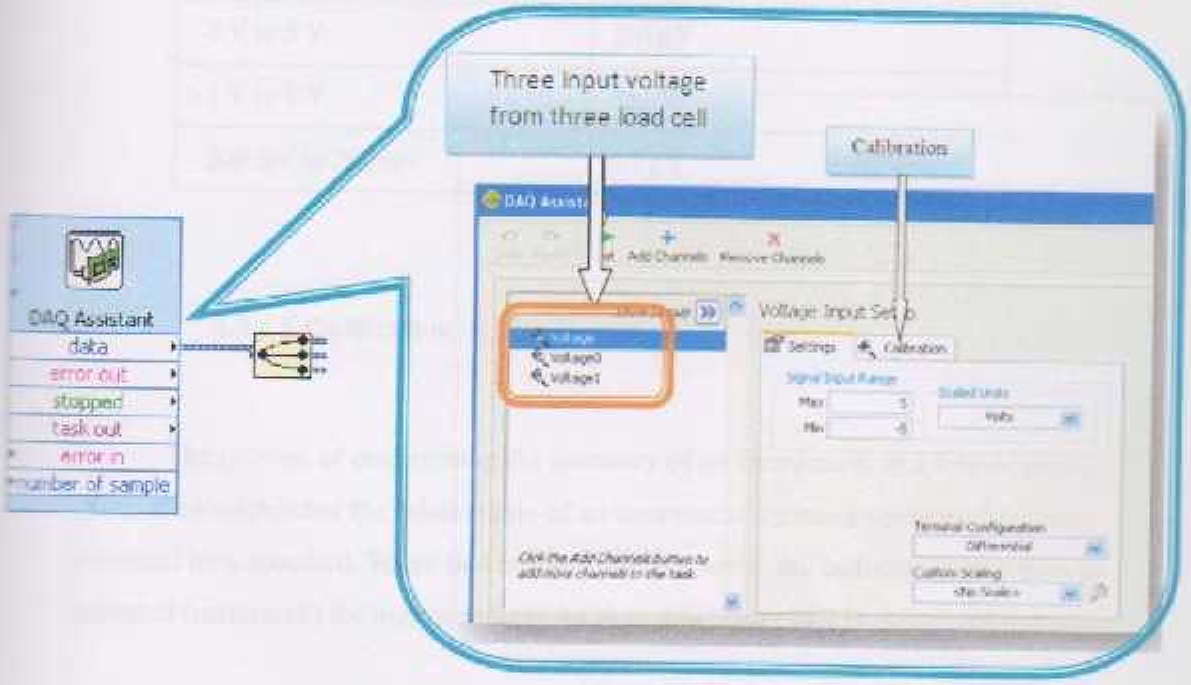


Figure (4.11): DAQ assistance

4.3.4.4 Analog Input

Input range refers to the set of input voltages that an analog input channel can digitize with the specified accuracy. The DAQ amplifies or attenuates the AI signal depending on the input range, you can individually program the input range of each AI channel on the DAQ device.

The input range affects the resolution of the M Series device for an AI channel so resolution refers to the voltage of one ADC code and the DAQ 6221 has the following input rang as shown in table(4.1)

Table (4.1): DAQ input range

Input Range	Nominal Resolution Assuming 5% Over Range
–10 V to 10 V	320 μV
-5 V to 5 V	160 μV
–1 V to 1 V	32 μV
–200 mV to 200 mV	6.4 μV

4.3.4.5 Calibration

The process of determining the accuracy of an instrument, in a formal sense, calibration establishes the relationship of an instrument's measurement to the value provided by a standard. When that relationship is known, the instrument may then be adjusted (calibrated) for best accuracy. As shown in figure (4.11)

4.3.4.6 Filter signals (low pass filter)

Since the signals have large noisefrom the environmentso low pass filters is needed to reduce this noise, and attenuate it from the signals, in DAQ the filter has variety of setting to ensure the best filter as shown in figure(4.12) .

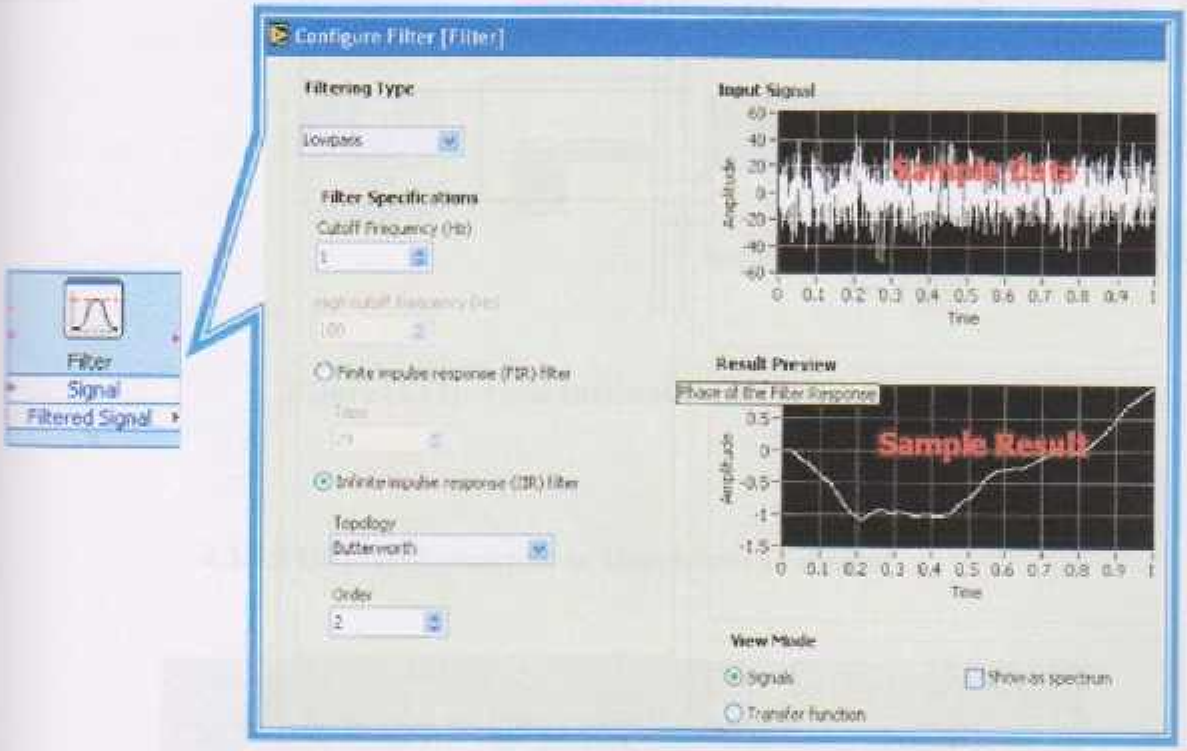


Figure (4.12): Filter setting in LabVIEW

4.3.4.7 Insert filtered signals to formulaas shown in figure (4.13)

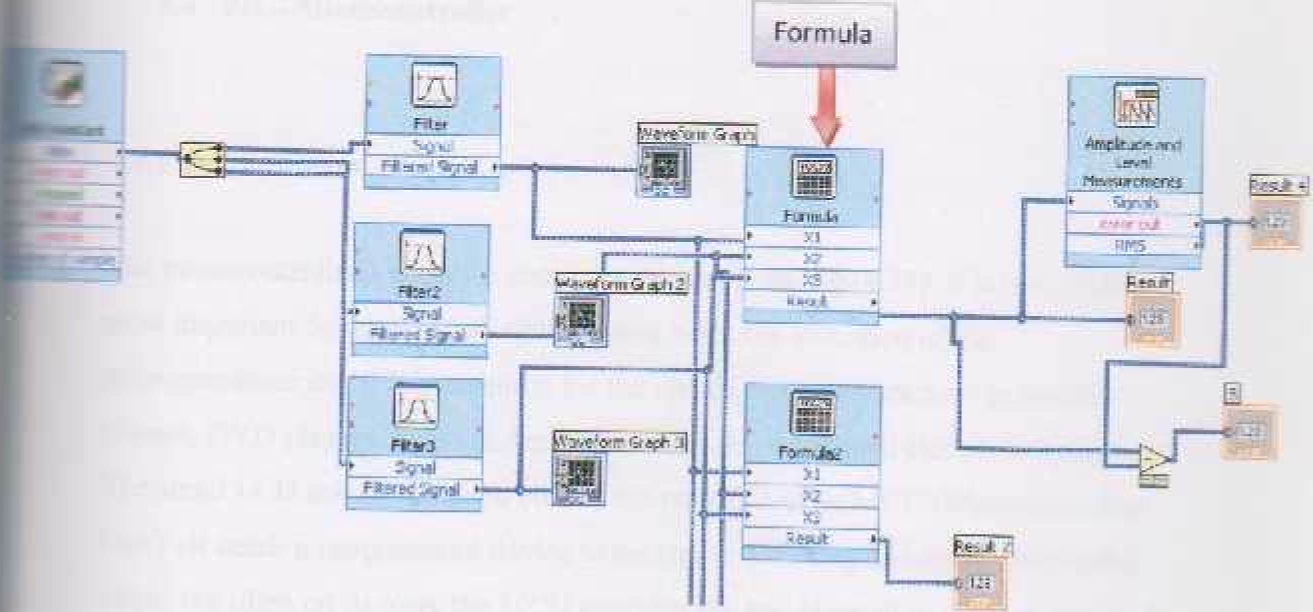


Figure (4.13): Total Internal Connection in LabVIEW

4.3.4.8 Display(Numerical or Graphical) as shown

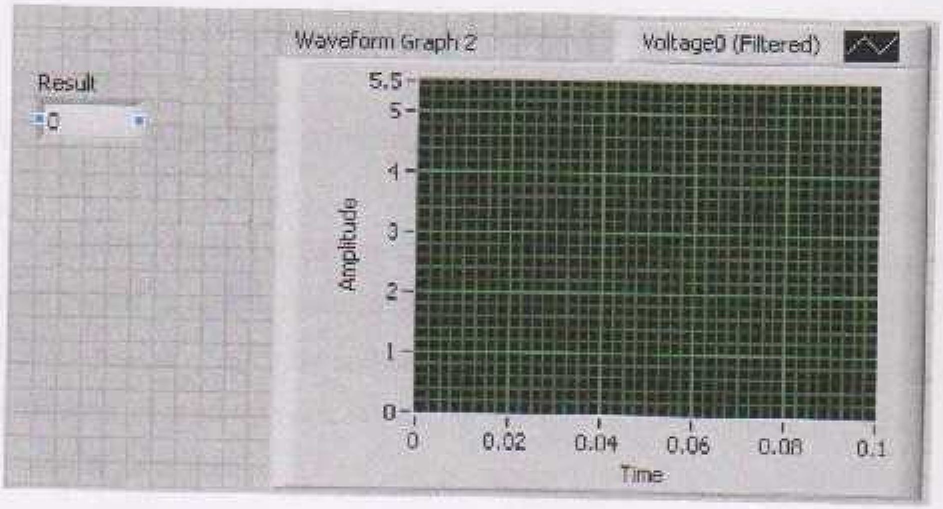


Figure (4.14): Numerical and Graphical Display

4.4 PIC- Microcontroller

4.4.1 Introduction

The microcontrolleris simply a computer on a chip see fig.(4.15). It is one of the most important developments in electronics since the invention of the microprocessor itself. It is essential for the operation of devices such as mobile phones, DVD players, video cameras, and most self-contained electronic systems. The small LCD screen is a good clue to the presence of an MCU (Microcontroller Unit) –it needs a programmed device to control it. Working sometimes with other chips, but often on its own, the MCU provides the key element in the vast range of small, programmed devices which are now common place.[7]

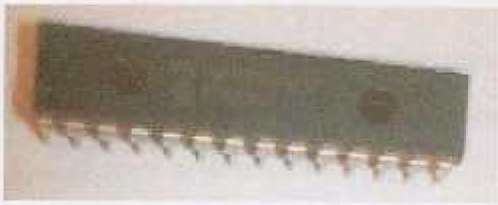


Figure (4.15): Microcontroller chip

4.4.2. How to select PIC- Microcontroller

This project can be implemented by using PIC microcontroller, because many features are helped us to build suitable model such as: number of bit resolution, I/O ports, addition to size of memory and number of instructions, remember this device measure of tenth gram so we need to estimate number of bit resolution for ADC (analog – digital - converter) .

Maximum load is applied on device 3Kg divided on 3 load cells ,that's mean 1Kg for each load cell, another hand maximum voltage of analog input for PIC is 5V we should divide full scale 5V on 1Kg, that is equal 5mv/1g(which 0.5mV/0.1g or LSB=0.5mV), as a result we need 10000 level for ADC, in other word $10000=2^n$; n=13.288bits, a suitable PIC is 14 bit resolution for ADC (LSB=0.3mV), PIC of 14 bit is difficult to fixing on board as shown in fig(4.16), its needed special machine to fix it beside it's not available .

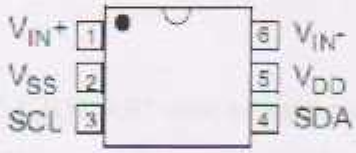
Figure(4.16): MCU with 14 bit ADC

So we are selecting 10bit (ADC) microcontroller see table (4.2) and using external (ADC)Such as MCP3425 see fig.(4.17) from Microchip technology to implement project and give success results.

Properties for PIC 10bit ADC ,it's called 18F4550

Table (4.2) PIC18F4550 properties

Device	Program Memory		Data Memory		I/O	10-Bit A/D (ch)	CCP/ECCP (PWM)	SPP	MSSP		EAUSART	Comparators	Timers 8/16-Bit
	Flash (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)					SPI	Master I^2C^{TM}			
PIC18F4550	32K	16384	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3



Figure(4.17): MCP3425 ADC

The MCP3425 " 16-Bi t Analog- to-Digital Converter with I2C Interface and On-Board Reference" is a single channel low-noise, high accuracy ΔΣ A/D converter with differential inputs and up to 16 bits of resolution, one pin is connected with PIC, it's called Serial Data Pin (SDA).see Appendix (B.5)

Table (4.3) :LSB Size Of Various Bit Conversion Modes

Bit Resolutions	LSB (V)
12 bits	1 mV
14 bits	250 µV
16 bits	62.5 µV

4.4.3. PIC pin out

Fig.(4.18): PIC 18F4550 pin out

PIC has five ports" A,B,C,D,E" used as input and output, it has 13 analog channels, in this project will be used 3 channels to take signals from 3 load cells.

4.4.4. Conditioning Circuit "Amplification and Filtration"

The signals of load cells are weak and noisy, we should be build amplification and filtration circuit as shown in fig.(4.19) to amplify and improve form of signals " in other word to obtain pure and cleaned 5DCV enter on port of PIC". Pure signals are useful to accomplishment the device, if else we have error in measurements and the device cannot achieve its goal.

Filtered and amplified signals enter into external ADC to digitizing and to process equations or mathematical model.

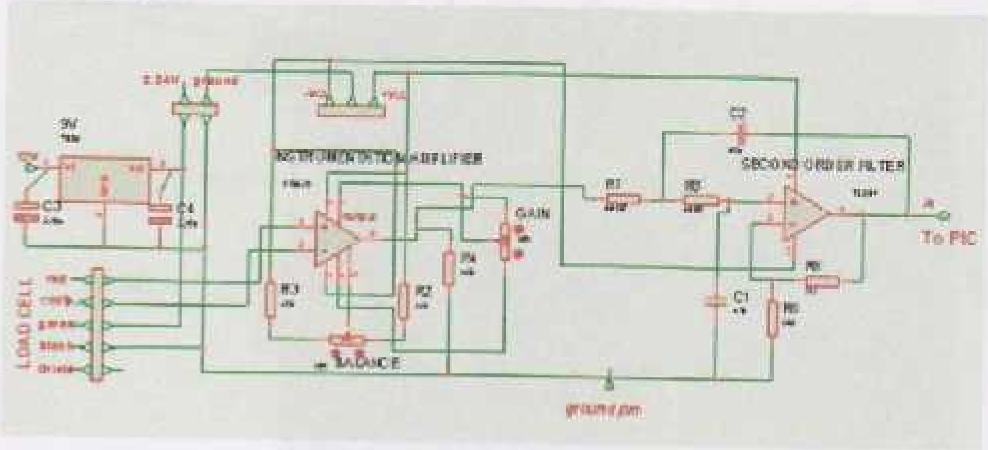


Figure 4.19: Amplification and filtration circuit

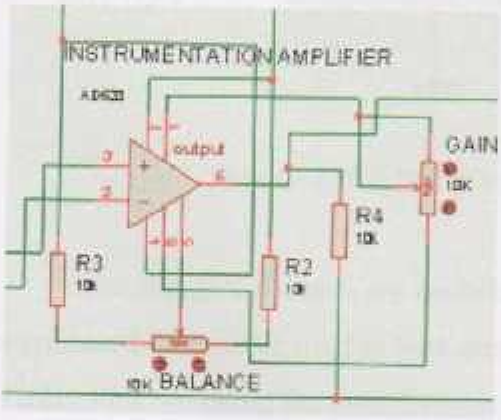


Figure 4.19.a: Instrumentation amplifier AD620

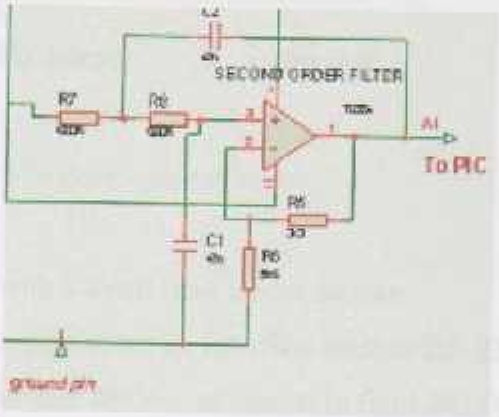
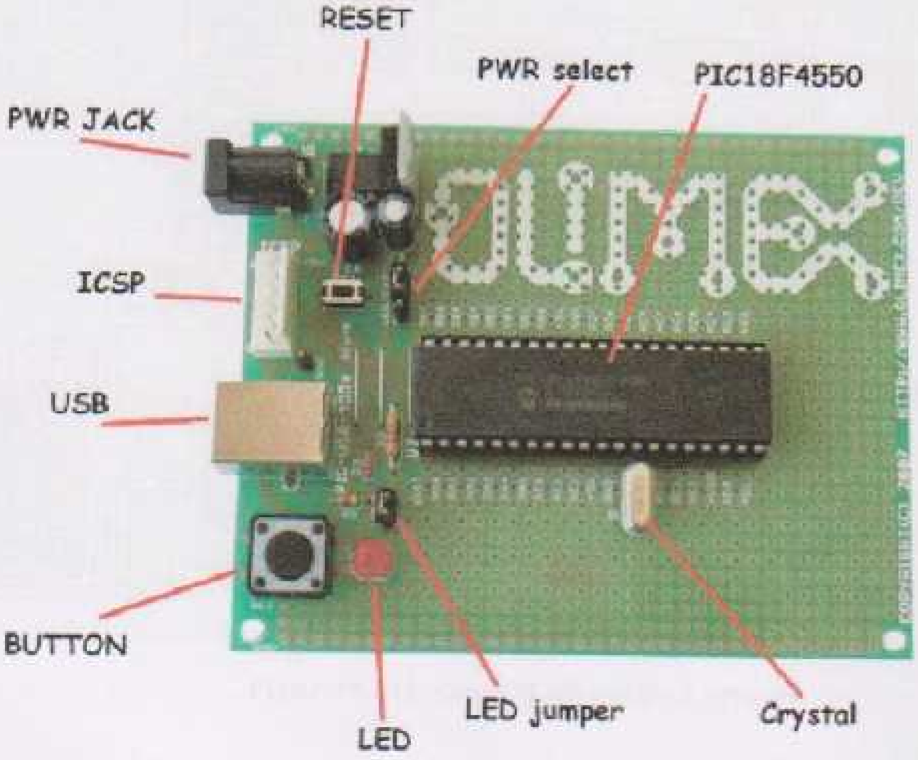


Figure 4.19.a:Second order filter

4.4.5 How to implement mathematical model

The equations can be built them by C-language or by assemble language However, C-language is more easy than assemble language in this case.

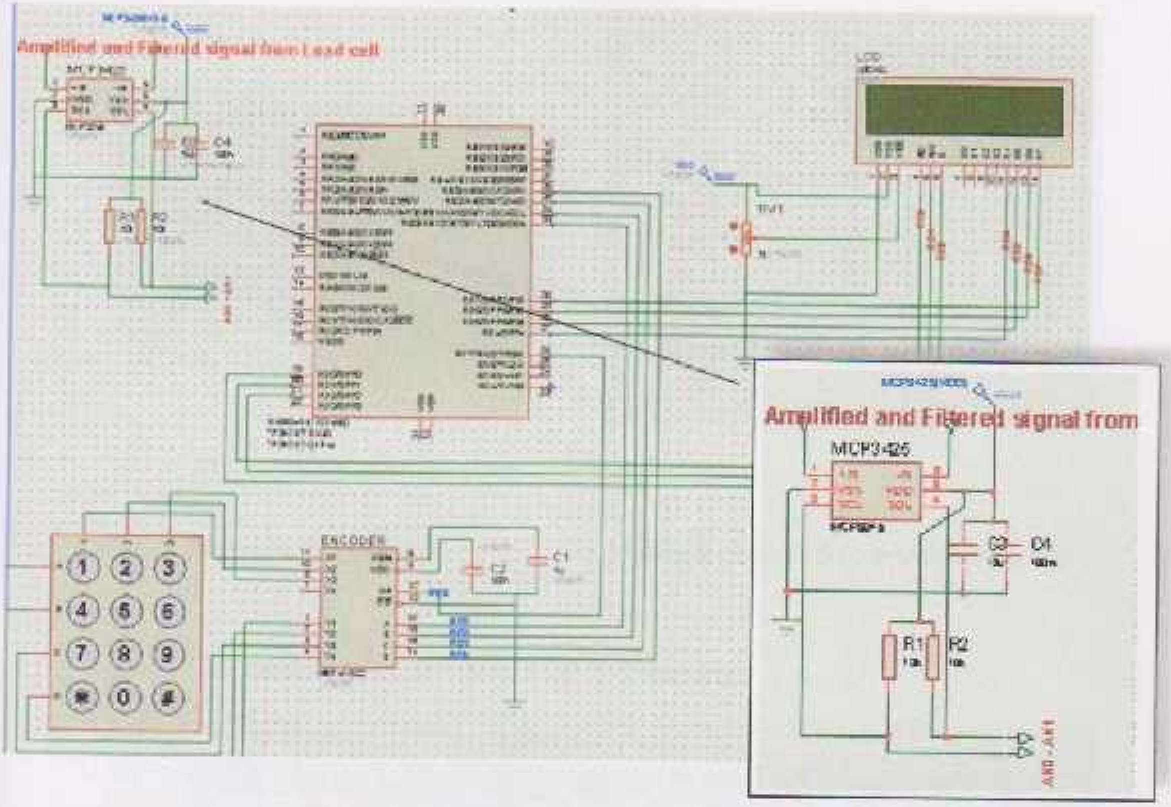
After build equations on C language and compile it to hex code by MPLAB program should be installed it on PIC by programmer, so many of the higher end flash based PICs can also self-program (write to their own program memory).



Figure(4.20): PIC-USB-4550 development board

Developments boards are available with a small boot loader factory programmed that can be used to load user programsover an interface such as **RS-232 or USB,** thus obviating the need for a programmer device. as shown in fig(4.20).On other hand can be used Simple serial port **ICSP** programmers :These generally rely on driving the PIC's Vss line negative to get the necessary voltage differences from programming. Hence they are compact and cheap but great care is needed if using them for in circuit programming. see appendix (B.4)

4.5.6 Hardware connection for all parts



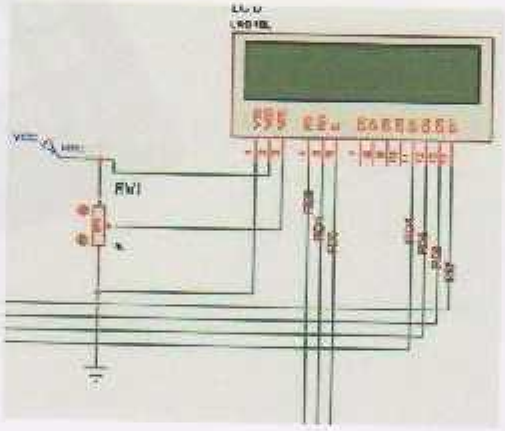
Figure(4.21): connect all parts of project

4.4.7 Input and output units:

PIC has not any input and output units exist in its basic construction, but can connect many I/O on it, such as swishes, keypads, for input unit and also LED's , LCD's, for output.

In this situation we need to use Keypad for input and LCD for outputs, to display the results, as shown in figure (4.22) can see appendix(B.6).

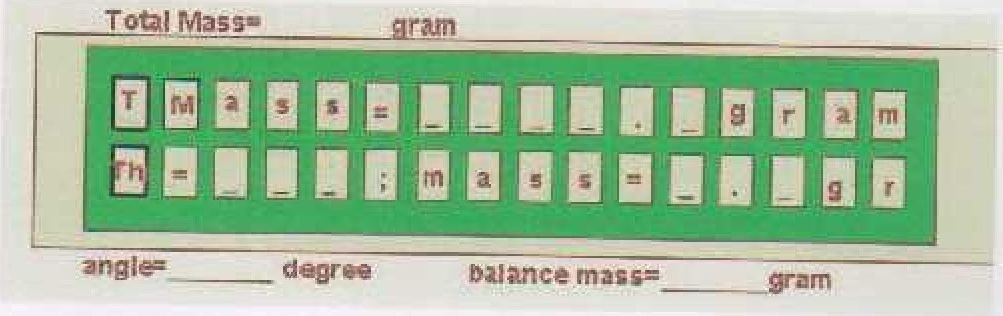
Keypad gets instruction from the user to determine the way the process will be go, as shown figure (4.24).



Figure(4.22.a): LCD

Figure(4.22.b): LCD connection with PIC

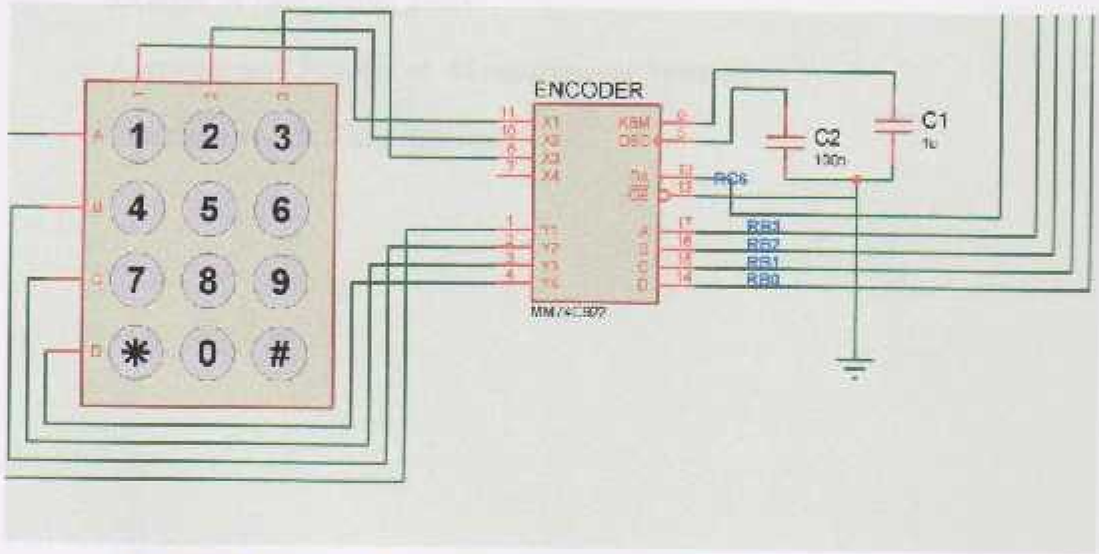
The results will be shown on LCD as following:



Figure(4.23): Form of Display results

To interface keypad with microcontroller should be add encoder MM74C922 can see appendix(B.7)to transform hex code to BCD " binary coded decimal" code, so the encoder is out 4bit go directly to PIC such as Port B. as shown fig.(4.25.

Figure (4.24): Keypad



Figure(4.25): interface circuit between PIC and keypad

Will be discussed experimental testing in the next chapter.

Chapter Five

Experimental Testing

Testing Operation

Properties of a Disc had been tested in Jelanco factory

Groups of Important Tests

Accurate and Precise of Measurement Systems

The final result from this test

5.1 Testing Operation

The first test has applied in the project was measured the external signal from load cell to sure it corrected as following:

- When voltage supply equal 10V, Output is 0.9766 mV/V at full load 1.5Kg. so when apply 9V at 1Kg output is equal 8.2mV.
- Input impedance is 415±20Ω before connected
- Output impedance is 350±3Ω before connected

Signals from the load cells is very weak and noisy as a resultthe signal should be amplified and filtered. So the signal entered in AD620 instrumentation amplifier then amplify signal to 5V at load 1Kg, but noise stay on signal although use hardware filter as shown fig(5.1),the amount of noise range about 80 mV ($V_{p.p}$).

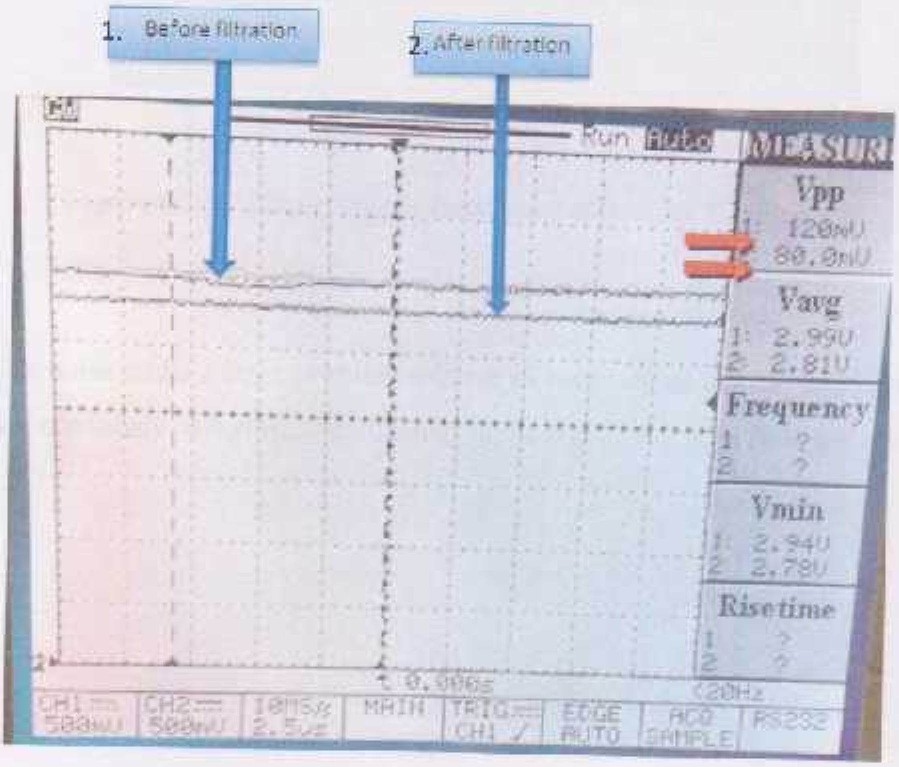
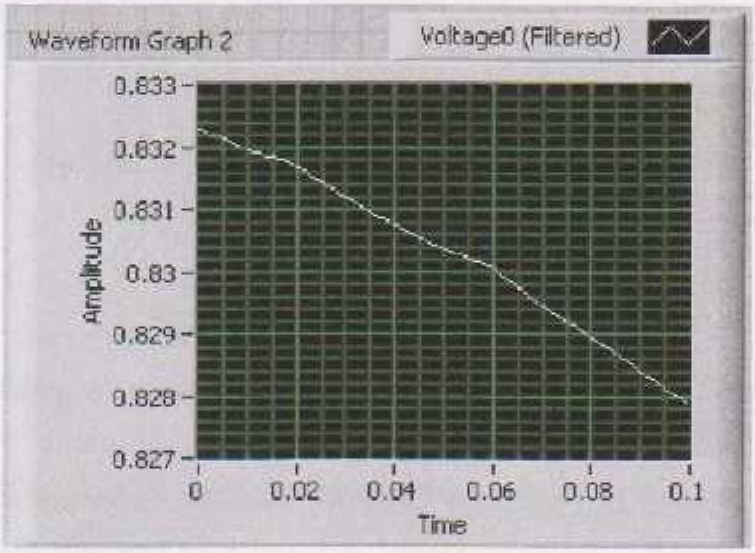


Figure (5.1): load cell signal

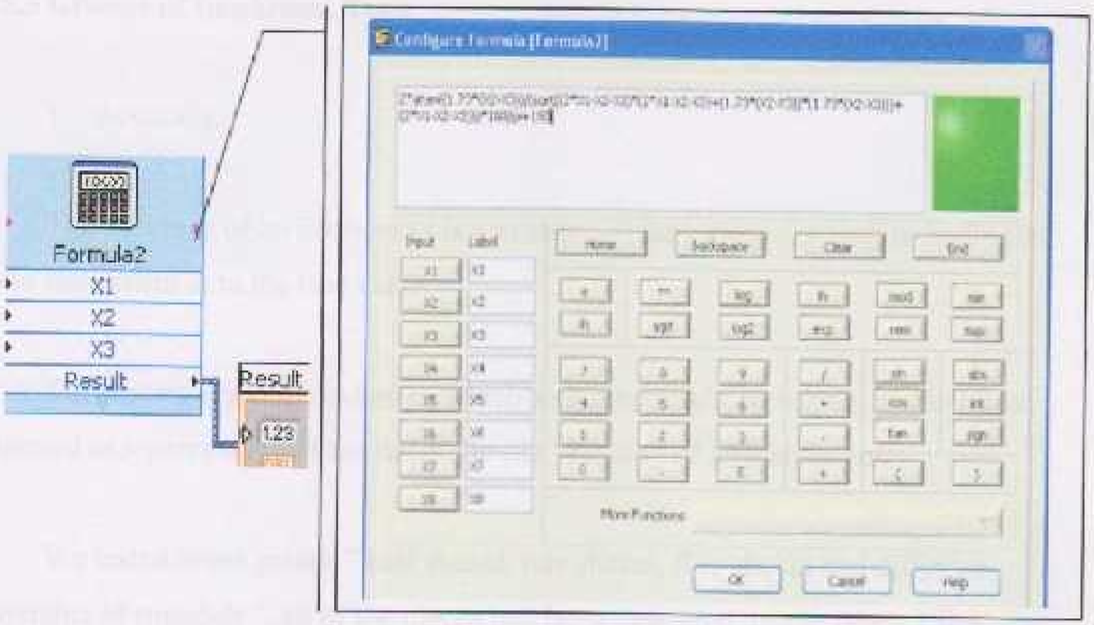
When use DAQ system , there is no need to use hardware filter because LabVIEW (interface program) has an inner filter as show in previously chapter.

But the noise remained as shown fig(5.2), in spite of use many techniques to remove noise such as instrumentation amplifier " AD620" , capacitors and resistor used as integrator, buffer circuit and other techniques.



Figure(5.2): Output signal from load cell with filtration

The noise make a large problem relative to accuracy of device, this is results are appear obviously when was build equation as shown fig(5.3), then get a resultin indicator



Figure(5.3):formula window

After building all equations on LabVIEW " formula window" then run program.

5.2 Properties of a Disc had been tested in Jelanco factory

Disc has 9" diameter , used to cutting material , the minimum unbalance mass acceptable is less than 3gram. As shown fig(5.4)

Figure(5.4): Disc under test

5.3 Groups of Important Tests

1. Accuracy.

The accuracy of an instrument is a measure of how close the output reading of the instrument is to the true value.

The inaccuracy is the extent to which a reading might be wrong, and is often quoted as a percentage of the full-scale (f.s.) reading of an instrument.

We tested seven pieces " half shekel, one shekel, five shekel and different weights of roundels ", all of the pieces had been measured on electronic Libra has error ±0.05 gram. Not that the real values of materialpieces taken by electronic labra has ±0.01 error gm

Table (5.1): Accuracy testing.

Number of piece	$\frac{1}{2}$ shekel	1 shekel	5 shekel	1	2	3	4
Real value	6.46	3.54	8.18	0.800	0.32	0.52	4.32
Measured value	6.26	3.43	8.28	0.808	0.34	0.606	4.24

Max Error is = 3%

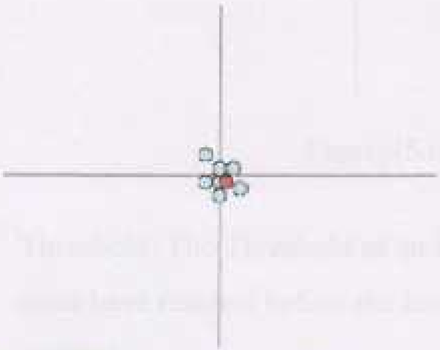
2. Precision (repeatability)

The precision of an instrument is a measure of the scatter of results obtained from measurements as a result of random errors. It described the closeness of the agreement occurring between the results obtained for a quantity when it is measured several times under the same conditions.

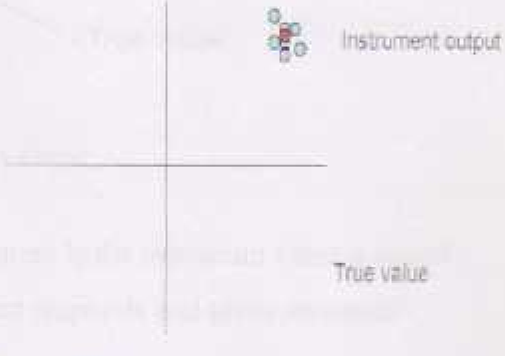
Table (5.2): Repeatability testing.

Number of trial	1	2	3	4	5	6	7
1 shekel(3.54gr)	3.43	3.23	3.83	3.43	3.23	3.66	3.23
Roundel has(4.32)gr.	4.24	4.24	4.44	4.64	4.04	4.44	4.24

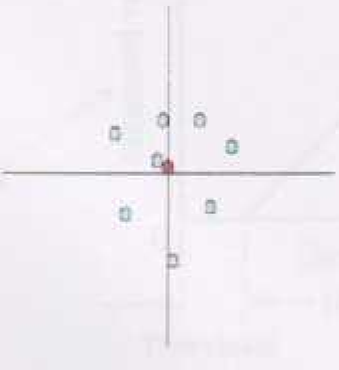
5.4 Accurate and Precise of Measurement Systems



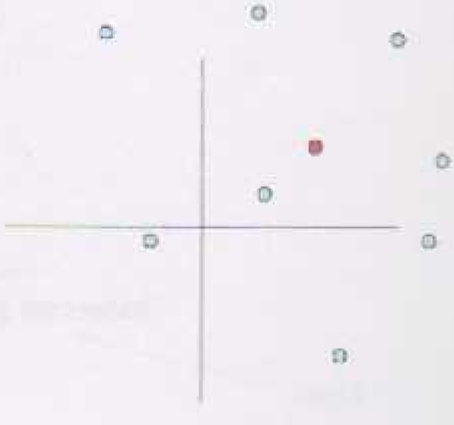
Figure(5.5.a): Accurate and precise



Figure(5.5.b): Not accurate but precise



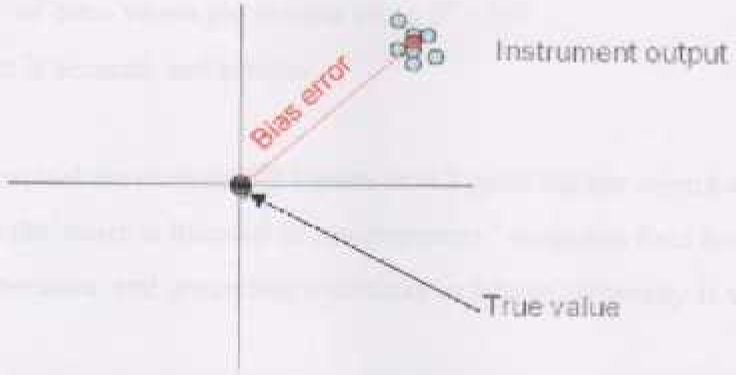
Figure(5.5.c): accurate but not precise



Figure(5.5.d): neither accurate nor precise

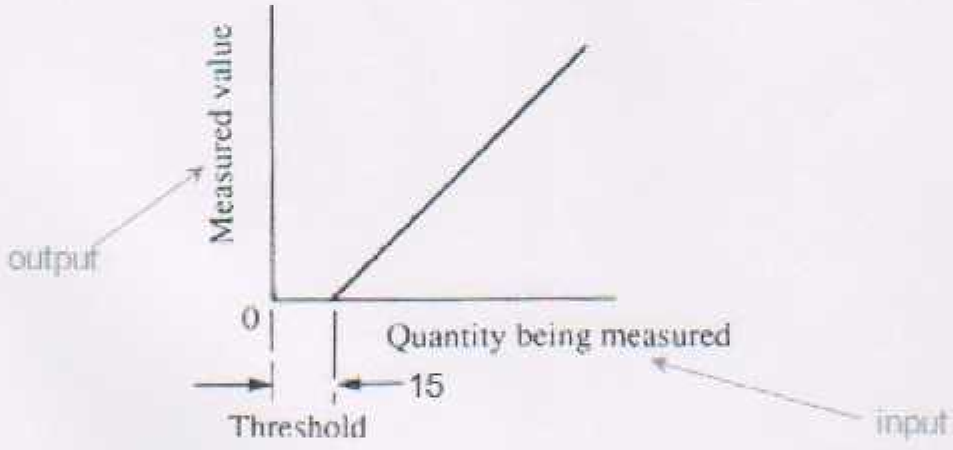
- Average value of measurements
- Random measurements

3. Bias error: is the difference between the average and the true value (constant error)



Figure(5.6):Bias error

4. Threshold: The Threshold of an instrument is the minimum value a signal must have reached before the instrument responds and gives an output reading.



Figure(5.7): Threshold

5.5 The final result from this test

- Total mass of disc is about 298-300 gram, and the amount of mass must be added to make a disc is correct, it's about 1.7-2.3 gram
- Angle of mass where put masses about $0^\circ - 10^\circ$
- System is accurate and precise

The our goal are measured 0.1 gram or 0.2 gram but her cannot estimate this value because the noise is founded in environments " magnetic field form devices" beside to temperature and grounding electricity in labs of university is very bad .

So the noise signal has not a formal pattern to estimate it and subtract from original signal to get a pure signal, as a result the error is randomly and has not get a constant Percentage of error.

Chapter six

Problem, Recommendation and Conclusion

6.1 Problems

1) Noise

The main problem that appears in this project is high noise (unstable signals) that affect to the measurements in spite of using a regulator circuit and special IC that is specialized for using the load cell.

The main source of this noise is the absent of earthling in the building and the electrical device in the lab of the university.

2) Electronic parts

The late or unfounded electronic parts or IC's affects to the development and improvement of our project in spite of the using of load cell needed special electronic part such as it needed special operational amplifier called AD620 which is available only in Israel land needed a lot of time to arrive to us, another electronic parts such that microcontroller PIC with 14 bit resolution which is unavailable and the available version below it has 10 bit resolution only.

3) Missing lab for graduation mechatronics

In our university there isn't a free lab which available to serve the projects and when there is available lab the supervisor is busy or unavailable which late the working of graduation projects.

And the missing of available supervisor for milling and lathe lab.

6.2 **Recommendation**

The project will be at final able to produce a new machine which has variety application in industry, not only testing of grinding and cut of wheels discs ,but also used for testing of static balance in variable type of systems.

6.3 Conclusion

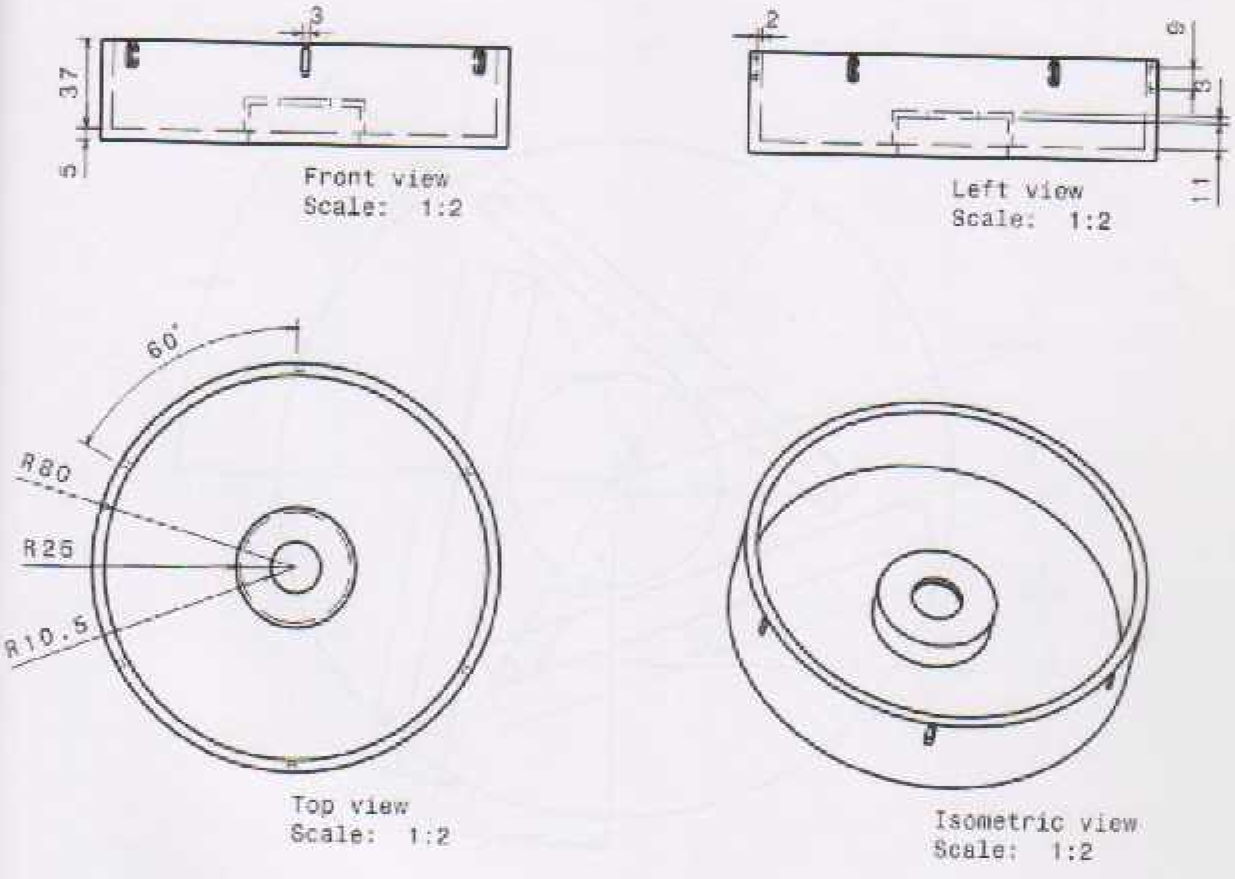
The device is very important for Jelanco factory to improve quality test of products, but until this moment the implementation of device is passing through many obstacles, the major problem is noise and unstable signal on a constant value, although are used many electronic circuit which expectedly remove or reduced noise

So the attempts and experiments are continuous to realize the device and succeed on it

Appendices :

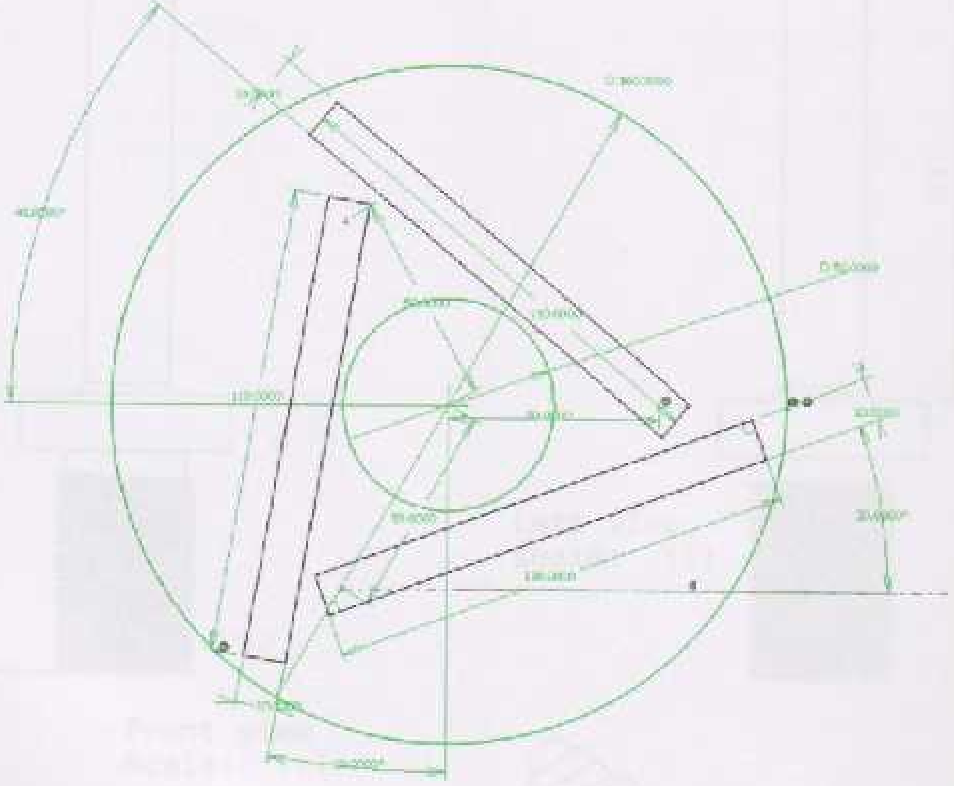
Appendix (A): Mechanical design

1. Load cells container

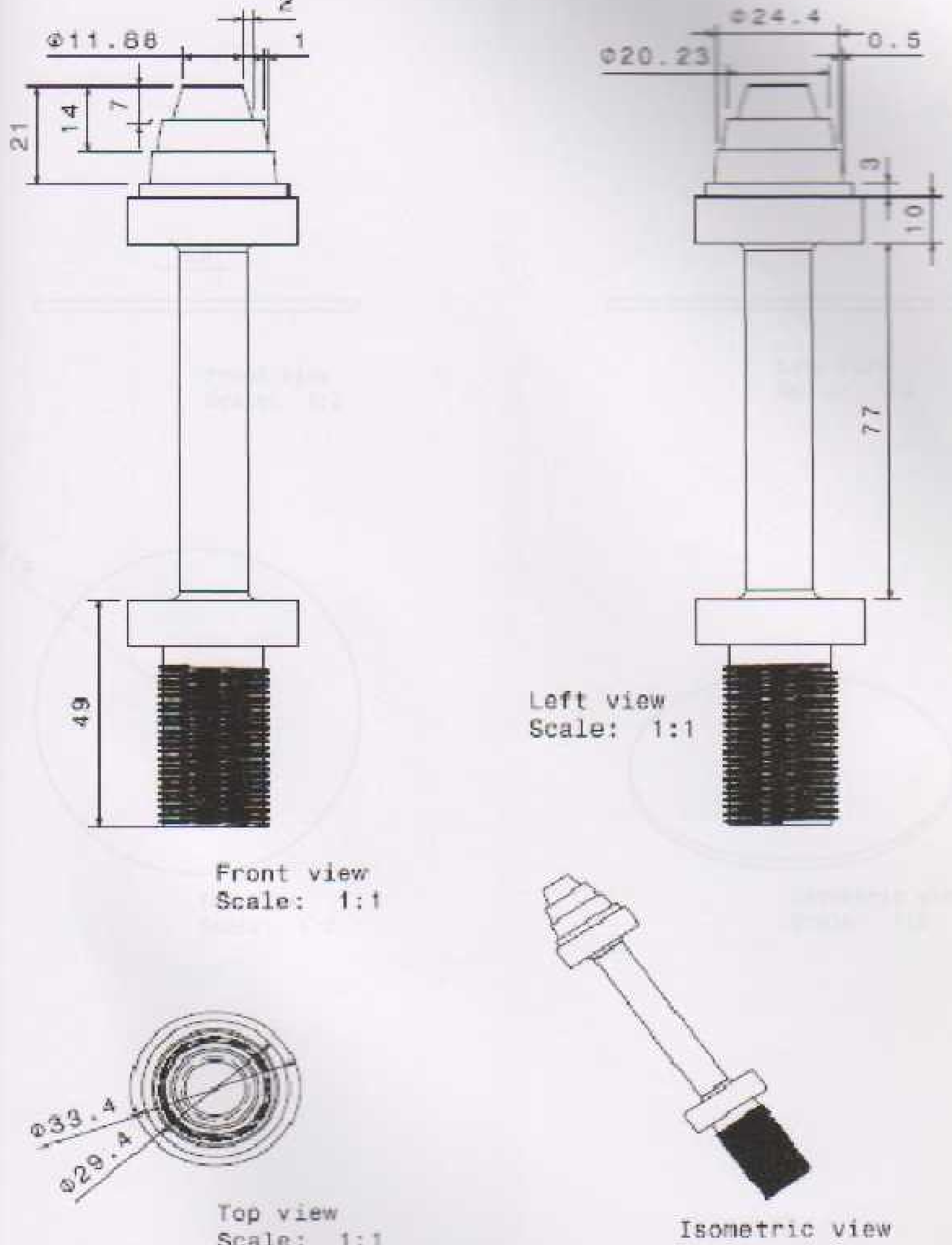


The container is made from Aluminum

2. distribution of load cells inside the container



3. Discs holder:



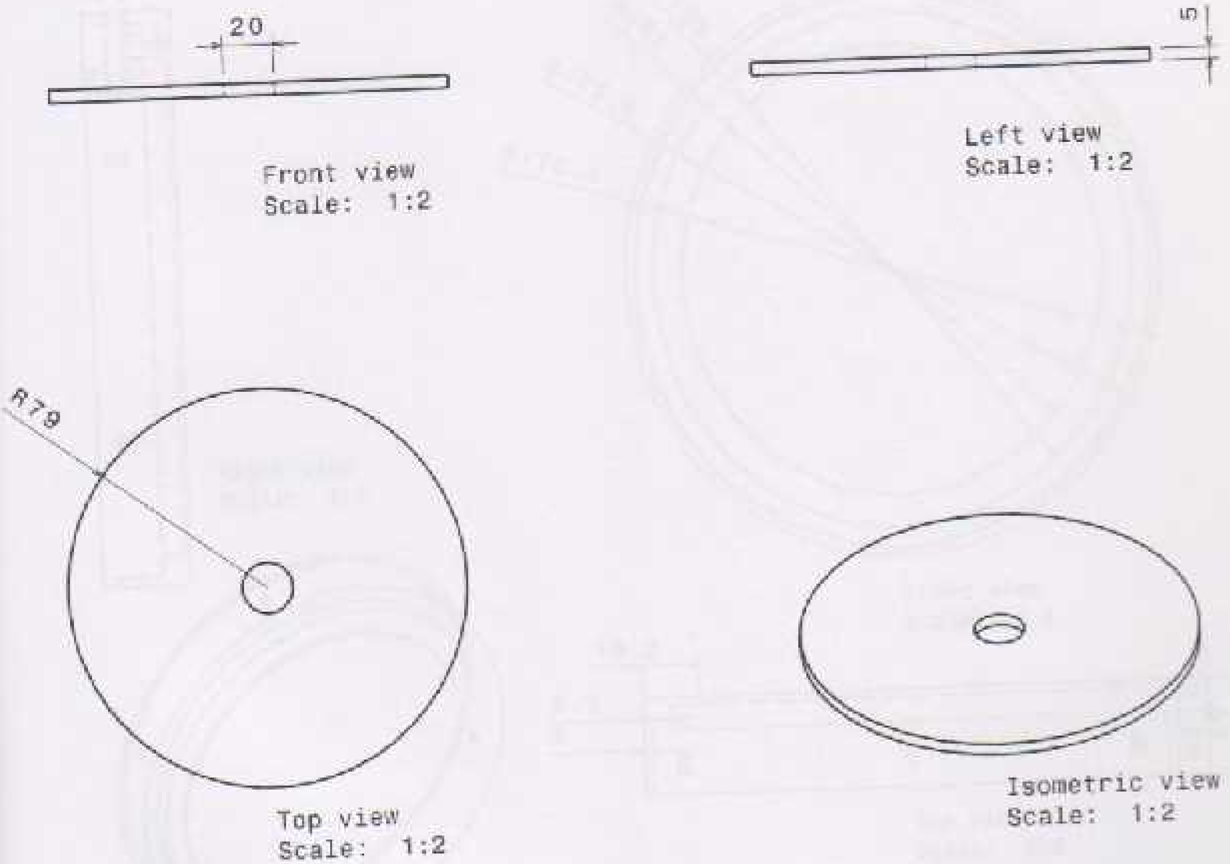
Front view
Scale: 1:1

Left view
Scale: 1:1

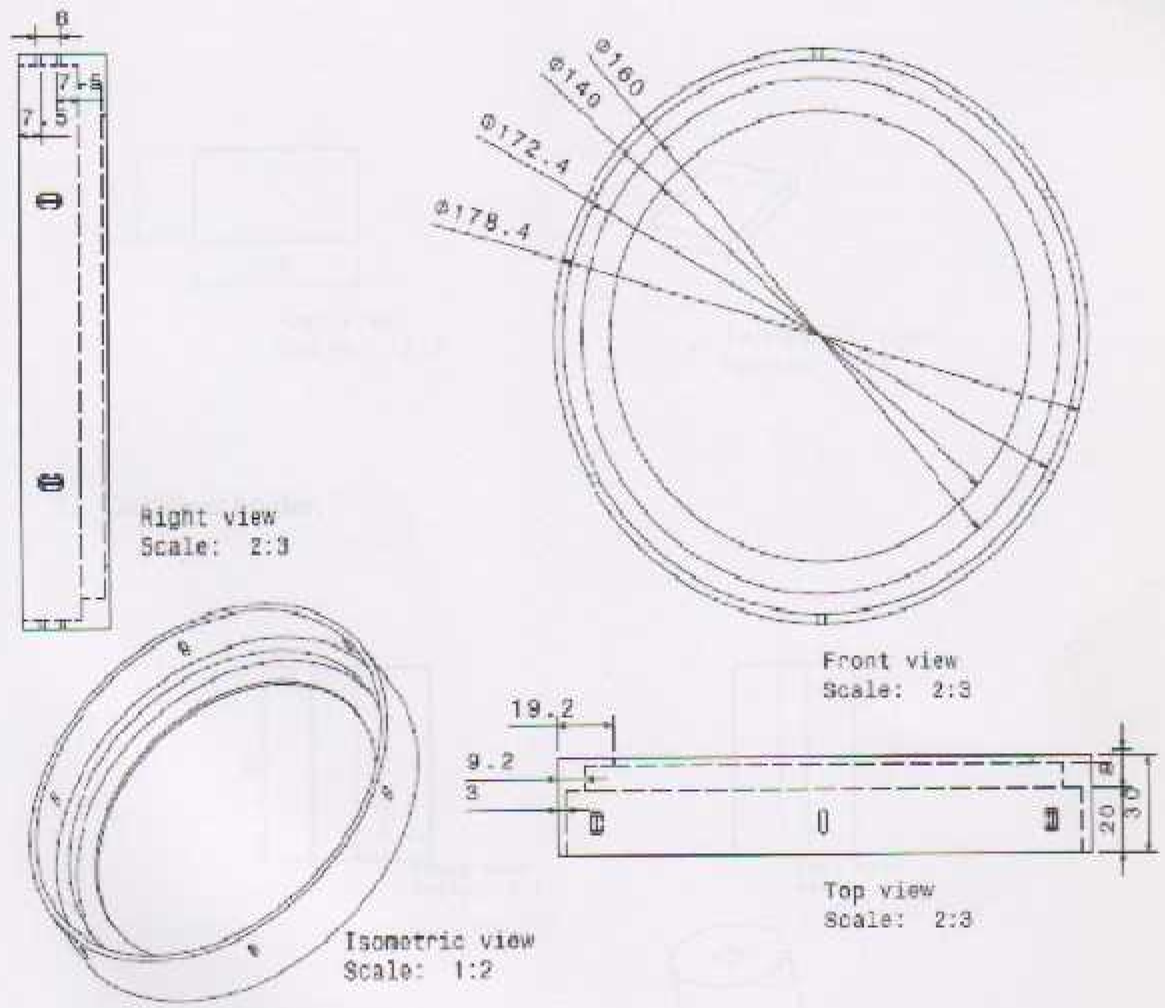
Top view
Scale: 1:1

Isometric view
Scale: 1:2

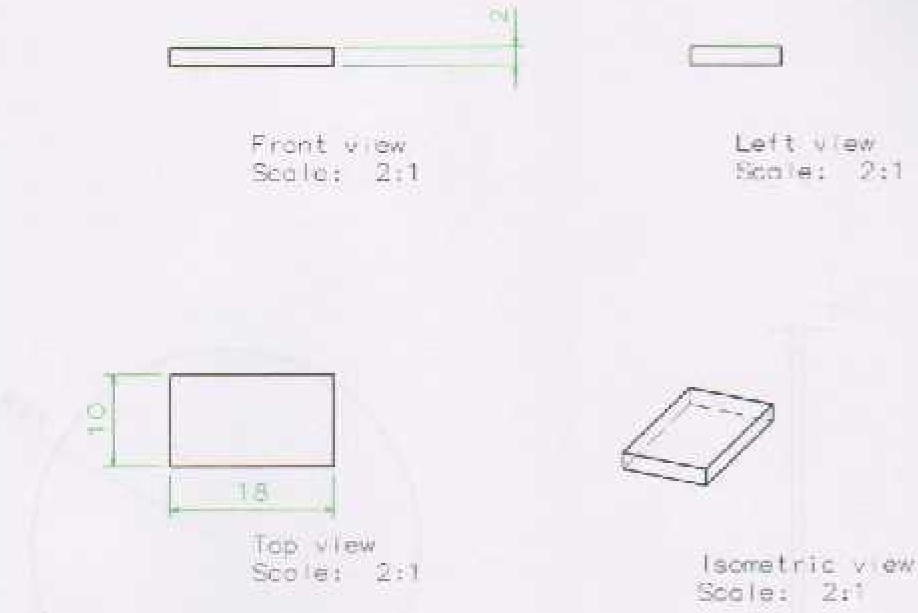
4. Base holder of Discs:



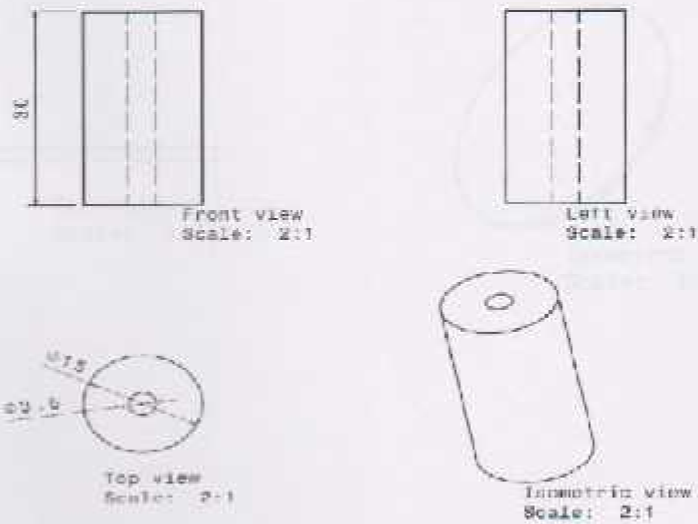
5. Calibration part:



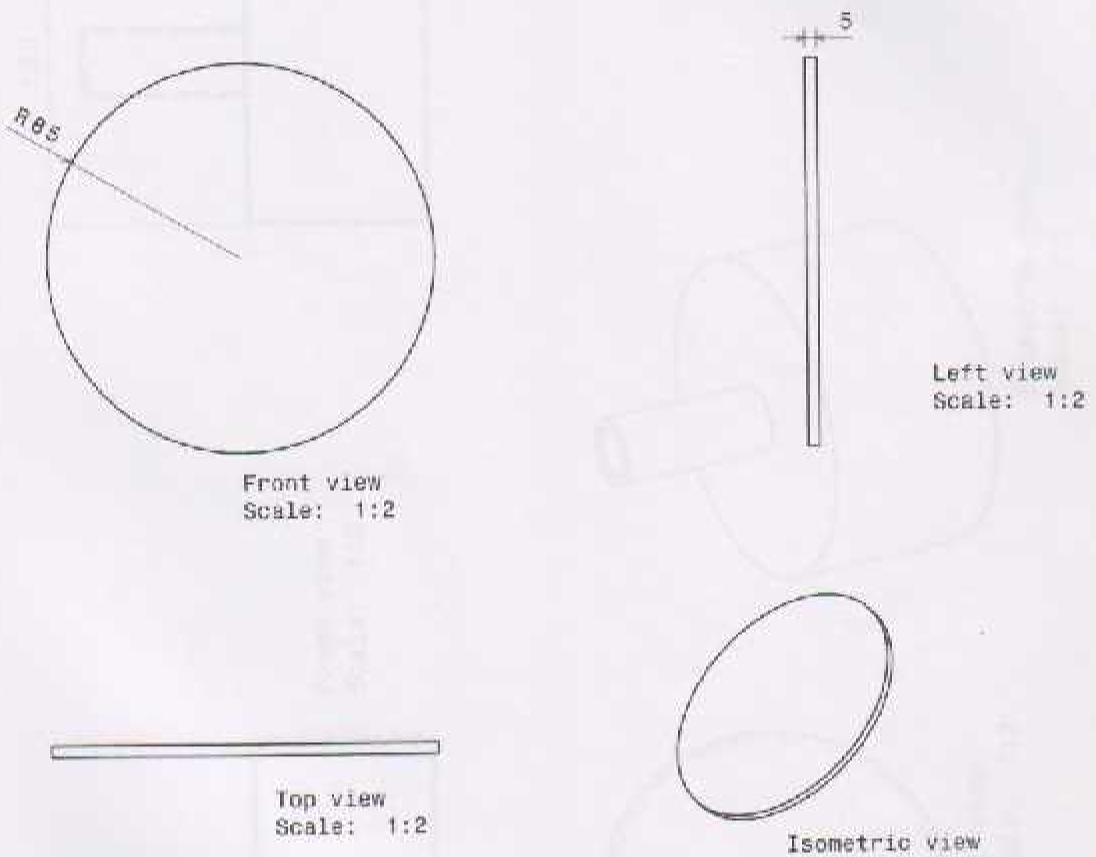
6. Stand of load cells:



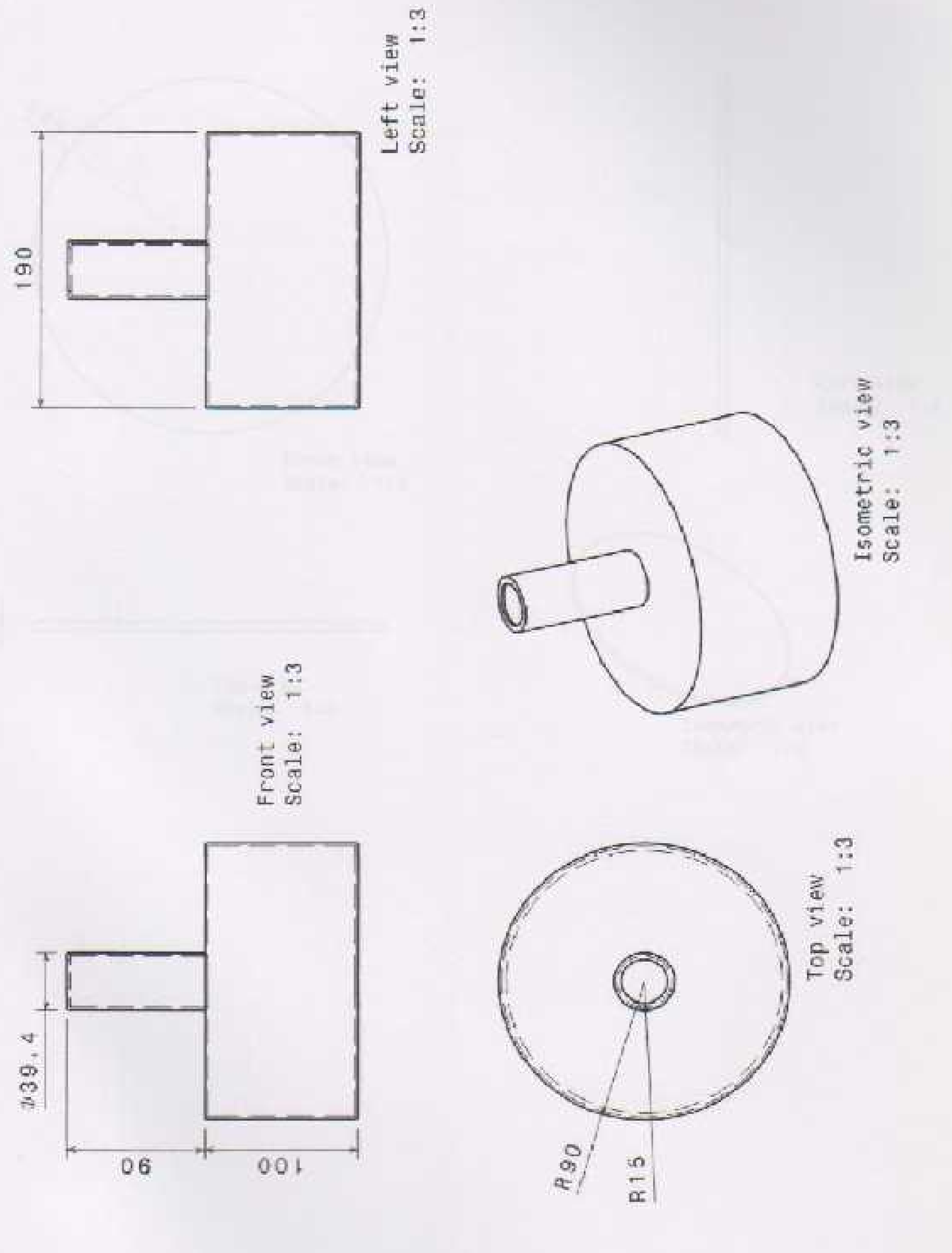
7. Container holder:



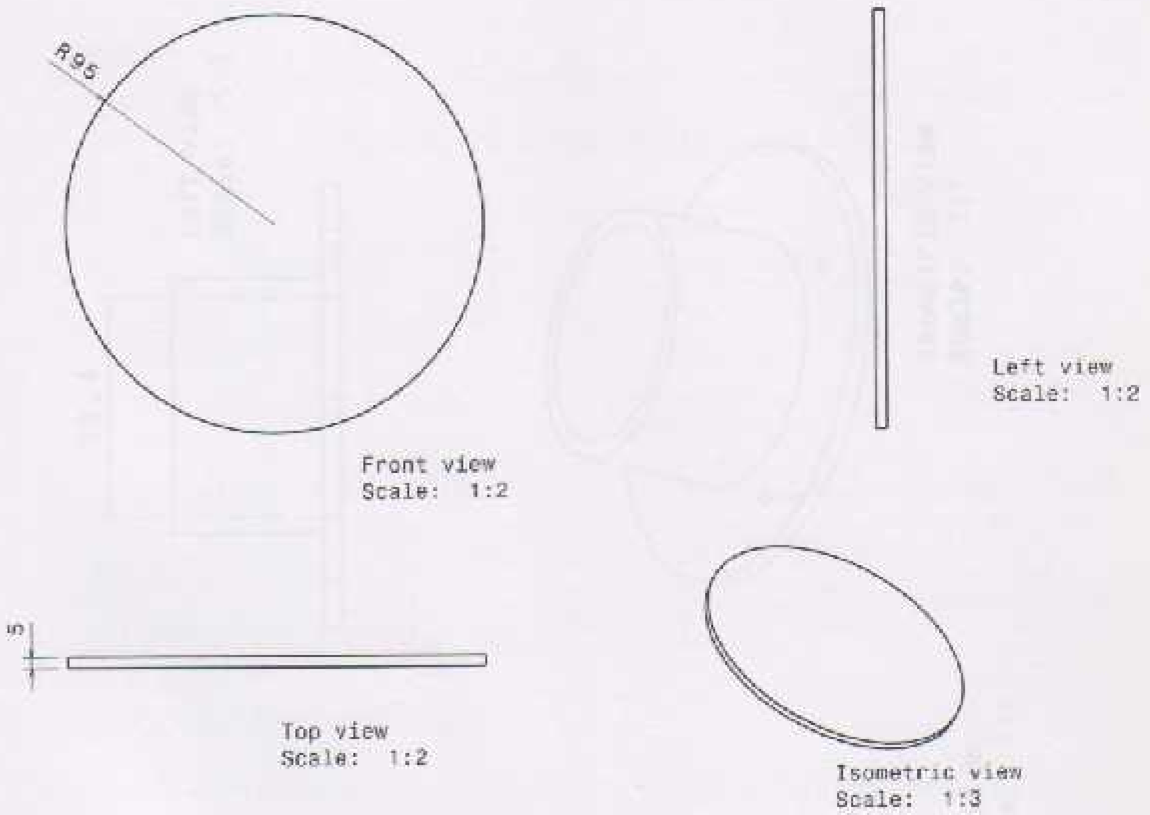
8. Electronic base:



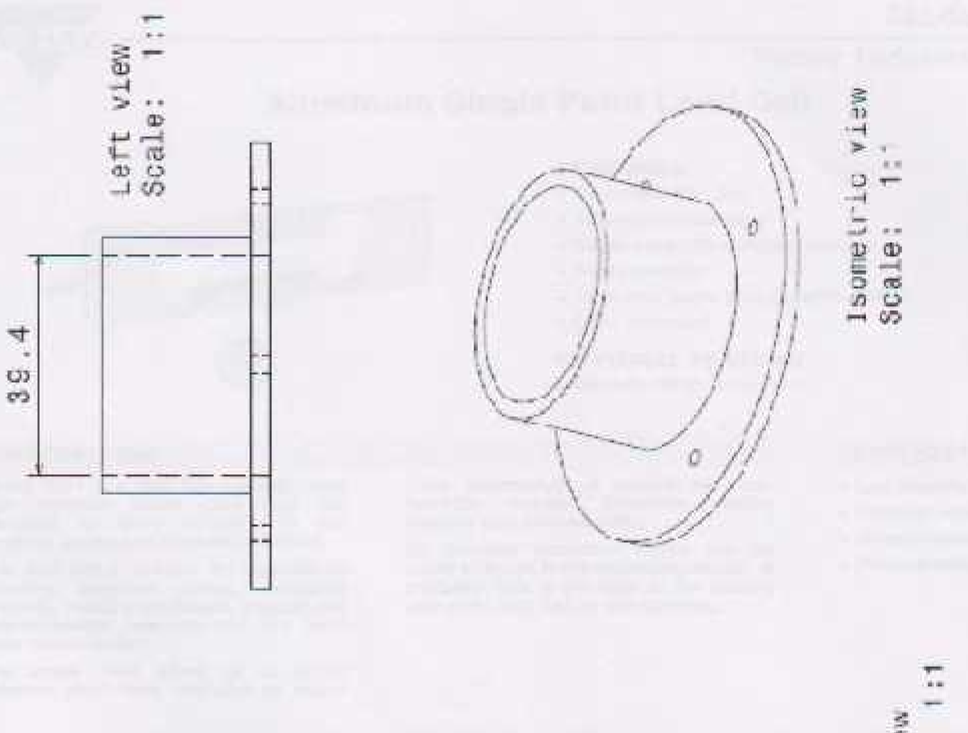
9. The cover:


Left view
Scale: 1:3
190
Front view
Scale: 1:3
Ø39.4
90
100
Isometric view
Scale: 1:3
Top view
Scale: 1:3
R90
R15

10. The base:


R95
Left view
Scale: 1:2
Front view
Scale: 1:2
5
Top view
Scale: 1:2
Isometric view
Scale: 1:3

11. holder angular



Appendix (B): electronic and control parts:

B.1 Load cell.

VISHAY.

Model 1004

Vishay Tedea-Huntleigh

Aluminum Single Point Load Cell

FEATURES

- Capacities 0.3 - 3kg
- Aluminum construction
- Single point 200 x 200mm platform
- IP66 protection
- Total error better than 0.0067% of R.O.
- OIML approved

OPTIONAL FEATURE

- Capacity 200g at 0.8mV/V

DESCRIPTION

Model 1004 is a very low capacity, very high precision single point load cell designed for direct mounting in low capacity scales and precision balances.

This load cell is suitable for applications including jewellery scales, analytical balances, medical equipment, medical and pharmaceutical research and low level force measurement.

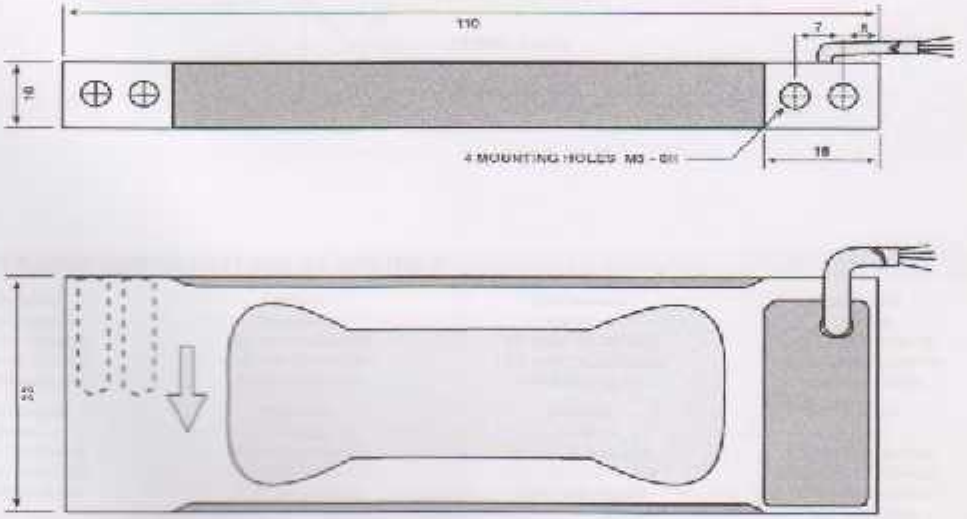
The model 1004 offers up to 30000 divisions short term precision at stable room temperature. A special two-stage humidity resistant protective coating assures long term reliability.

An overload protection device can be easily included in the application design. A threaded hole is provided in the loading end of the load cell for this purpose.

APPLICATIONS

- Low capacity scales
- Precision scales
- Jewelry scales
- Pharmaceutical scales

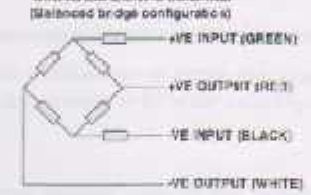
OUTLINE DIMENSIONS in millimeters



SPECIFICATIONS

PARAMETER	VALUE			UNIT
Accuracy class	GW	JW	C3	
Rated capacity-R.C. (E_{max})	0.3, 0.6, 1.5, 3			kg
Rated output-R.O.	0.9			mV/V
Rated output tolerance	0.1			±mV/V
Zero balance	0.045			±mV/V
Zero Return, 2 minutes	0.0100	0.0033		±% of applied load
Zero Return, 30 minutes			0.017	±% of applied load
Total Error (per OIML R60)	0.0100	0.0067	0.02	±% of rated output
Temperature effect on zero	0.0040		0.004	±% of rated output/°C
Temperature effect on output	0.0020		0.001	±% of load/°C
Eccentric loading error	0.0033			±% of rated load/cm
Temp. range, compensated	-5 to +40			°C
Temp. range, safe	-3 to +70			°C
Maximum safe central overload	150			% of R.C.
Ultimate central overload	250			% of R.C.
Excitation, recommended	10			Vdc or Vac rms
Excitation, maximum	15			Vdc or Vac rms
Input impedance	415±20			Ohms
Output impedance	350±3			Ohms
Insulation resistance	>2000			Mega-Ohms
Cable length	0.4			m
Cable type	4 wire, PVC, spiral shield			
Construction	Aluminum			
Environmental protection	IP66			
Platform size (max)	200 x 200			mm
Recommended torque	2.0			N*m

WIRING SCHEMATIC DIAGRAM
(Balanced bridge configuration)



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*Asia except China

B.2DAQ

B.2.1 Specifications

Technical Sales
Israel
03 639 3737
ni.israel@ni.com

NI PCI-6221

16-Bit, 250 kS/s, 16 Analog Inputs

- Two 16-bit analog outputs (833 kS/s); 24 digital I/O; 32-bit counters
- NIST-traceable calibration certificate and more than 70 signal conditioning options
- Correlated DIO (8 clocked lines, 1 MHz)
- NI-MCal calibration technology for increased measurement accuracy
- Select high-speed M Series for 5X faster sampling rates or high-accuracy M Series for 4X resolution.
- NI-DAQmx driver software and NI LabVIEW SignalExpress interactive data-logging software

Overview

The National Instruments PCI-6221 is a low-cost multifunction M Series data acquisition (DAQ) board optimized for cost-sensitive applications. Also consider the high-speed M Series devices for 5X faster sampling rates or the high-accuracy M Series devices for 4X resolution and superior measurement accuracy.

Low-cost M Series devices incorporate advanced features such as the NI-STC 2 system controller, NI-PGIA 2 programmable amplifier, and NI-MCal calibration technology to increase performance and accuracy. To learn more about M Series technologies, device specifications, and information on recommended cables and accessories, please refer to the data sheet and specifications.

Driver Software

M Series devices work with multiple operating systems using three driver software options including NI-DAQmx, NI-DAQmx Base, and the Measurement Hardware DDK. Browse the information in the Resources tab to learn more about driver software or download a driver. M Series devices are not compatible with the Traditional NI-DAQ (Legacy) driver.

Application Software

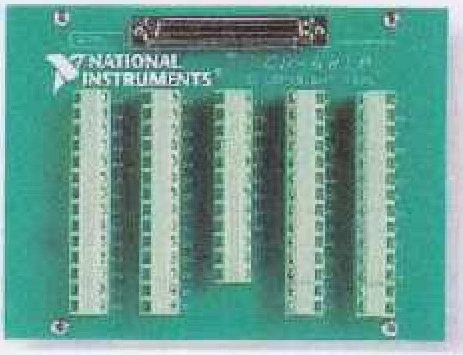
Every M Series data acquisition device includes a copy of NI LabVIEW SignalExpress so you can quickly acquire, analyze, and present data without programming. In addition to LabVIEW SignalExpress, M Series data acquisition devices are compatible with the following versions (or later) of NI application software – LabVIEW 7.x, LabWindows™/CVI 7.x, or Measurement Studio 7.x; or LabVIEW with the LabVIEW Real-Time Module 7.1. M Series data acquisition devices are also compatible with Visual Studio .NET, C/C++, and Visual Basic 6.

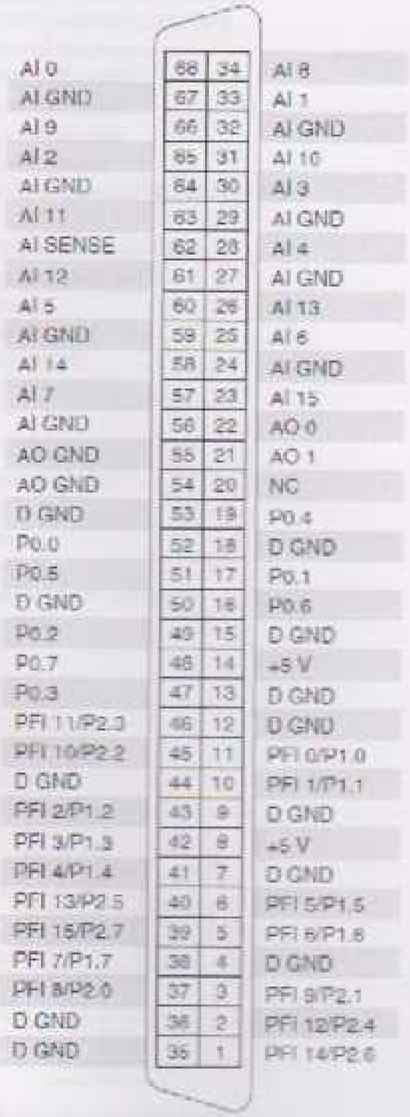
Specifications

Form Factor	PCI
OS Support	Windows, Real-Time, Linux, Mac OS
Measurement Type	Digital, Frequency, Quadrature encoder, Voltage
DAQ Product Family	M Series
LabVIEW RT Support	Yes
Analog Input	
Number of Channels	16 SE/8 DI
Sample Rate	250 kS/s
Resolution	16 bits
Simultaneous Sampling	No
Maximum Voltage Range	-10..10 V
Range Accuracy	3100 µV
Range Sensitivity	97.6 µV
Minimum Voltage Range	-200..200 mV
Range Accuracy	112 µV
Range Sensitivity	5.2 µV
Number of Ranges	4
On-Board Memory	4095 samples
Analog Output	
Number of Channels	2
Update Rate	833 kS/s
Resolution	16 bits
Maximum Voltage Range	-10..10 V
Range Accuracy	3230 µV
Minimum Voltage Range	-10..10 V
Range Accuracy	3230 µV
Current Drive (Channel/Total)	5 mA
Digital I/O	
Number of Channels	24 DIO
Timing	Hardware, Software
Maximum Clock Rate	1 MHz

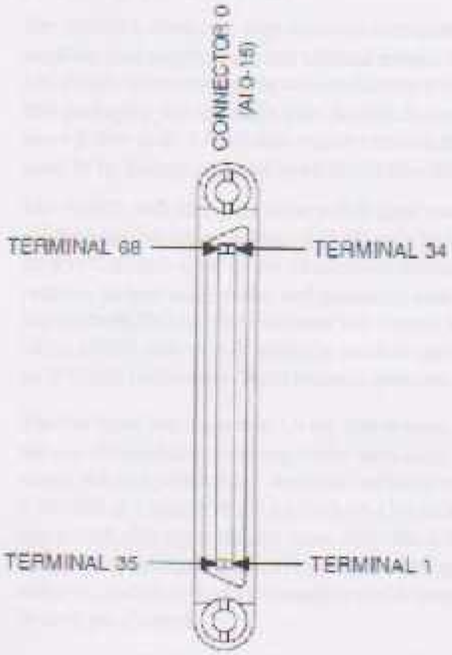
Maximum Input Range	0..5 V
Maximum Output Range	0..5 V
Input Current Flow	Sinking, Sourcing
Programmable Input Filters	Yes
Output Current Flow	Sinking, Sourcing
Current Drive (Channel/Total)	24 mA/448 mA
Watchdog Timer	No
Supports Programmable Power-Up States?	Yes
Supports Handshaking I/O?	No
Supports Pattern I/O?	Yes
Counter/Timers	
Number of Counter/Timers	2
Resolution	32 bits
Maximum Source Frequency	80 MHz
Minimum Input Pulse Width	12.5 ns
Logic Levels	TTL
Maximum Range	0..5 V
Timebase Stability	50 ppm
GPS Synchronization	No
Pulse Generation	Yes
Buffered Operations	Yes
Debouncing/Glitch Removal	Yes
Number of DMA Channels	2
Timing/Triggering/Synchronization	
Synchronization Bus (RTSI)	Yes
Triggering	Digital
Physical Specifications	
Length	15.5 cm
Width	9.7 cm
I/O Connector	68-pin VHDCI female

B2.2 Terminals:





NC = No Connect



B.3 AD620 Operational Amplifier

ANALOG DEVICES

Low Cost Low Power Instrumentation Amplifier

AD620

FEATURES

Easy to use
- Gain set with one external resistor
  - (Gain range 1 to 10,000)
- Wide power supply range (±2.3 V to ±18 V)
- Higher performance than 3 op amp IA designs
- Available in 8-lead DIP and SOIC packaging
- Low power, 1.3 mA max supply current

Excellent dc performance (B grade)
- 50 µV max, input offset voltage
- 0.6 µV/°C max, input offset drift
- 1.0 nA max, input bias current
- 100 dB min common-mode rejection ratio (G = 10)

Low noise
- 9 nV/√Hz @ 1 kHz, input voltage noise
- 0.28 µV p-p noise (0.1 Hz to 10 Hz)

Excellent ac specifications
- 120 kHz bandwidth (G = 100)
- 15 µs settling time to 0.01%

APPLICATIONS

Weigh scales
ECG and medical instrumentation
Transducer interface
Data acquisition systems
Industrial process controls
Battery-powered and portable equipment

CONNECTION DIAGRAM

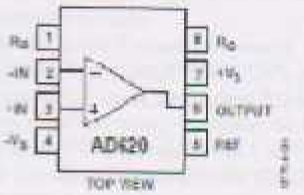


Figure 1. 8-Lead PDIP (N), CERDIP (Q), and SOIC (R) Packages

PRODUCT DESCRIPTION

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000. Furthermore, the AD620 features 8-lead SOIC and DIP packaging that is smaller than discrete designs and offers lower power (only 1.3 mA max supply current), making it a good fit for battery-powered, portable (or remote) applications.

The AD620, with its high accuracy of 40 ppm maximum nonlinearity, low offset voltage of 50 µV max, and offset drift of 0.6 µV/°C max, is ideal for use in precision data acquisition systems, such as weigh scales and transducer interfaces. Furthermore, the low noise, low input bias current, and low power of the AD620 make it well suited for medical applications, such as ECG and noninvasive blood pressure monitors.

The low input bias current of 1.0 nA max is made possible with the use of Superßeta processing in the input stage. The AD620 works well as a preamplifier due to its low input voltage noise of 9 nV/√Hz at 1 kHz, 0.28 µV p-p in the 0.1 Hz to 10 Hz band, and 0.1 pA/√Hz input current noise. Also, the AD620 is well suited for multiplexed applications with its settling time of 15 µs to 0.01%, and its cost is low enough to enable designs with one in-amp per channel.

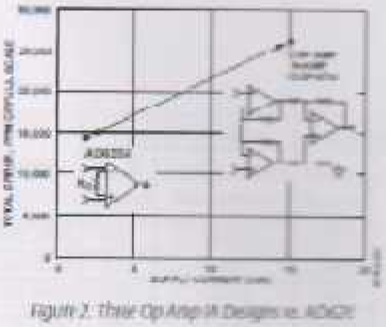


Figure 2. Three Op Amp IA Designs vs. AD620

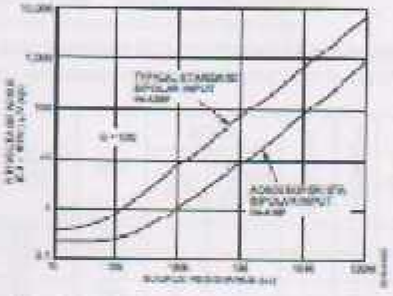


Figure 3. Total Voltage Noise vs. Source Resistance

B.4 PIC 18F4550

MICROCHIP PIC18F2455/2550/4455/4550

28/40/44-Pin, High-Performance, Enhanced Flash, USB Microcontrollers with nanoWatt Technology

Universal Serial Bus Features:

- USB V2.0 Compliant
- Low Speed (1.5 Mb/s) and Full Speed (12 Mb/s)
- Supports Control, Interrupt, Isochronous and Bulk Transfers
- Supports up to 32 Endpoints (16 bidirectional)
- 1-Kbyte Dual Access RAM for USB
- On-Chip USB Transceiver with On-Chip Voltage Regulator
- Interface for Off-Chip USB Transceiver
- Streaming Parallel Port (SPP) for USB streaming transfers (40/44-pin devices only)

Power-Managed Modes:

- Run: CPU on, peripherals on
- Idle: CPU off, peripherals on
- Sleep: CPU off, peripherals off
- Idle mode currents down to 5.8 μA typical
- Sleep mode currents down to 0.1 μA typical
- Timer1 Oscillator: 1.1 μA typical, 32 kHz, 2V
- Watchdog Timer: 2.1 μA typical
- Two-Speed Oscillator Start-up

Flexible Oscillator Structure:

- Four Crystal modes, including High Precision PLL for USB
- Two External Clock modes, up to 48 MHz
- Internal Oscillator Block:
  - 8 user-selectable frequencies, from 31 kHz to 8 MHz
  - User-tunable to compensate for frequency drift
- Secondary Oscillator using Timer1 @ 32 kHz
- Dual Oscillator options allow microcontroller and USB module to run at different clock speeds
- Fail-Safe Clock Monitor:
  - Allows for safe shutdown if any clock stops

Peripheral Highlights:

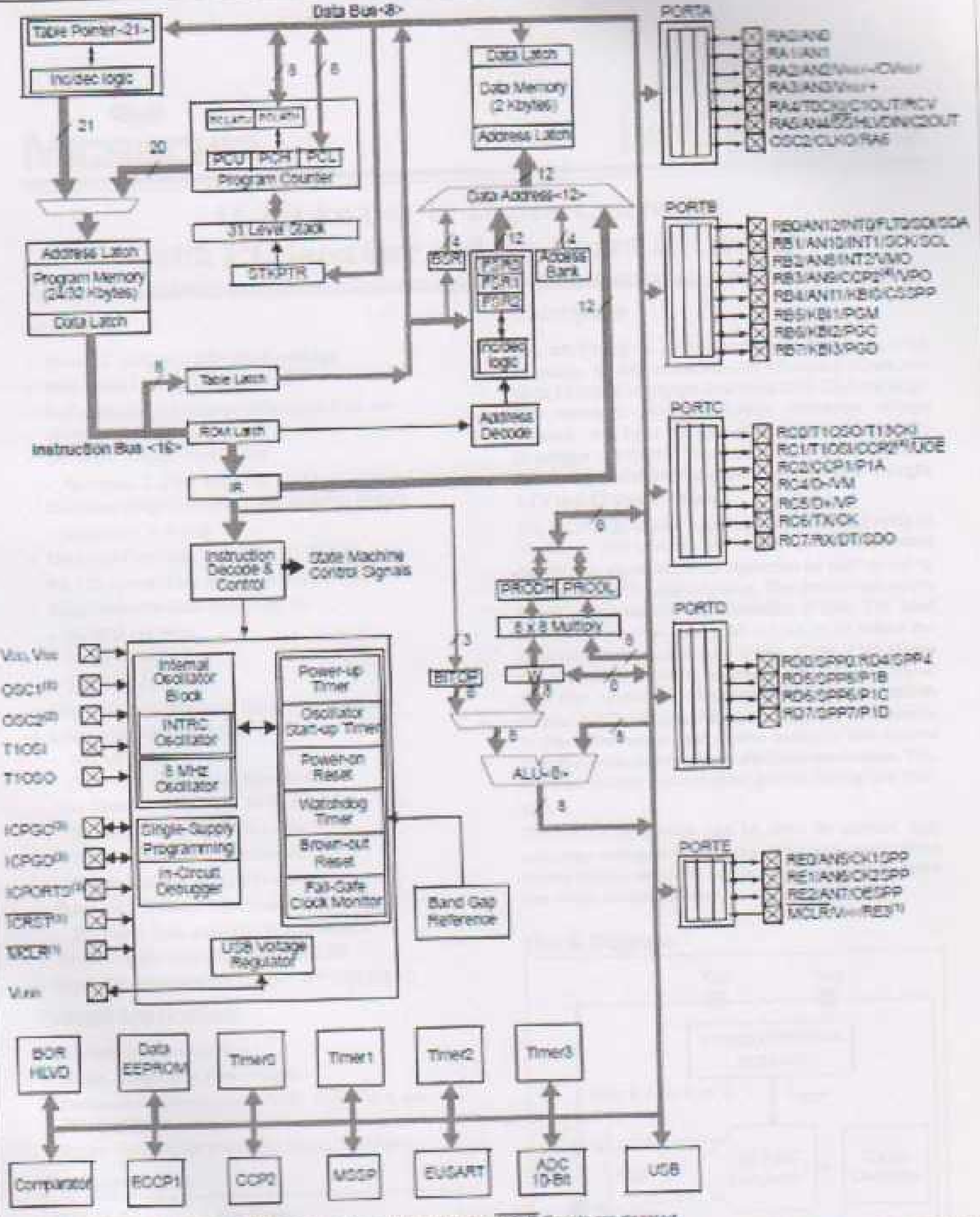
- High-Current Sink/Source: 25 mA/25 mA
- Three External Interrupts
- Four Timer modules (Timer0 to Timer3)
- Up to 2 Capture/Compare/PWM (CCP) modules:
  - Capture is 16-bit, max. resolution 5.2 ns (TCY/16)
  - Compare is 16-bit, max. resolution 83.3 ns (TCY)
  - PWM output: PWM resolution is 1 to 10-bit
- Enhanced Capture/Compare/PWM (ECCP) module:
  - Multiple output modes
  - Selectable polarity
  - Programmable dead time
  - Auto-shutdown and auto-restart
- Enhanced USART module:
  - LIN bus support
- Master Synchronous Serial Port (MSSP) module supporting 3-wire SPI (all 4 modes) and I²C™ Master and Slave modes
- 10-bit, up to 13-channel Analog-to-Digital Converter module (A/D) with Programmable Acquisition Time
- Dual Analog Comparators with Input Multiplexing

Special Microcontroller Features:

- C Compiler Optimized Architecture with optional Extended Instruction Set
- 100,000 Erase/Write Cycle Enhanced Flash Program Memory typical
- 1,000,000 Erase/Write Cycle Data EEPROM Memory typical
- Flash/Data EEPROM Retention: > 40 years
- Self-Programmable under Software Control
- Priority Levels for Interrupts
- 8 x 8 Single-Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 41 ms to 131s
- Programmable Code Protection
- Single-Supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins
- Optional dedicated ICD/ICSP port (44-pin devices only)
- Wide Operating Voltage Range (2.0V to 5.5V)

Device	Program Memory		Data Memory		I/O	10-Bit A/D (ch)	CCP/ECCP (PWM)	SPP	MSSP		EAUSART	Comparators	Timers 8/16-Bit
	Flash (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)					SPI	Master I²C™			
PIC18F2455	24K	12288	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F2550	32K	16384	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F4455	24K	12288	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3
PIC18F4550	32K	16384	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3

PIC18F4455/4550 (40/44-PIN) BLOCK DIAGRAM



Note 1: RE3 is multiplexed with $\overline{MCLR}$ and is only available when the $\overline{MCLR}$ Resets are disabled.

2: OSC1/CLKI and OSC2/CLKO are only available in select oscillator modes and when these pins are not being used as digital I/O. Refer to **Section 2.0 "Oscillator Configurations"** for additional information.

3: These pins are only available on 44-pin TQFP packages under certain conditions. Refer to **Section 25.9 "Special ICPORT Features (Designated Packages Only)"** for additional information.

4: RB3 is the alternate pin for CCP2 multiplexing.

B.5 MCP3425 16 bit Analog to digital converter

MICROCHIP

MCP3425

16-Bit Analog-to-Digital Converter with I²C Interface and On-Board Reference

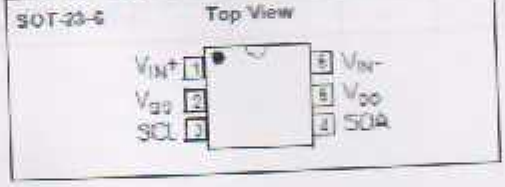
Features

- 16-bit ΔΣ ADC in a SOT-23-6 package
- Differential input operation
- Self calibration of Internal Offset and Gain per each conversion
- On-board Voltage Reference:
  - Accuracy: 2.048V ± 0.05%
- On-board Programmable Gain Amplifier (PGA):
  - Gains of 1, 2, 4 or 8
- On-board Oscillator
- INL: 10 ppm of FSR (FSR = 4.096V/PGA)
- Programmable Data Rate Options:
  - 15 SPS (16 bits)
  - 60 SPS (14 bits)
  - 240 SPS (12 bits)
- One-Shot or Continuous Conversion Options
- Low current consumption:
  - 145 µA typical (V_{DD}= 3V, Continuous Conversion)
- One-Shot Conversion (1 SPS) with V_{DD} = 3V:
  - 9.7 µA typical with 16 bit mode
  - 2.4 µA typical with 14 bit mode
  - 0.6 µA typical with 12 bit mode
- Supports I²C Serial Interface:
  - Standard, Fast and High Speed Modes
- Single Supply Operation: 2.7V to 5.5V
- Extended Temperature Range: -40°C to 125°C

Typical Applications

- Portable Instrumentation
- Weigh Scales and Fuel Gauges
- Temperature Sensing with RTD, Thermistor, and Thermocouple
- Bridge Sensing for Pressure, Strain, and Force.

Package Types



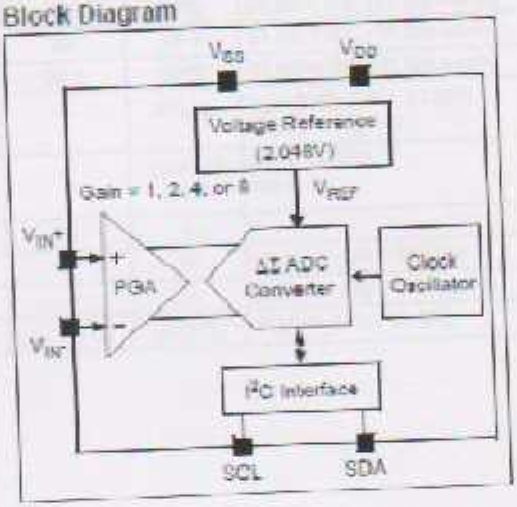
Description

The MCP3425 is a single channel low-noise, high accuracy ΔΣ A/D converter with differential inputs and up to 16 bits of resolution in a small SOT-23-6 package. The on-board precision 2.048V reference voltage enables an input range of ±2.048V differentially (Δ voltage = 4.096V). The device uses a two-wire I²C compatible serial interface and operates from a single 2.7V to 5.5V power supply.

The MCP3425 device performs conversion at rates of 15, 60, or 240 samples per second (SPS) depending on the user controllable configuration bit settings using the two-wire I²C serial interface. This device has an on-board programmable gain amplifier (PGA). The user can select the PGA gain of x1, x2, x4, or x8 before the analog-to-digital conversion takes place. This allows the MCP3425 device to convert a smaller input signal with high resolution. The device has two conversion modes: (a) Continuous mode and (b) One-Shot mode. In One-Shot mode, the device enters a low current standby mode automatically after one conversion. This reduces current consumption greatly during idle periods.

The MCP3425 device can be used for various high accuracy analog-to-digital data conversion applications where design simplicity, low power, and small footprint are major considerations.

Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

1.1 Absolute Maximum Ratings†

V_{DD} 7.0V
All inputs and outputs w.r.t V_{SS} .... –0.3V to V_{DD}+0.3V
Differential Input Voltage .... $|V_{DD} - V_{SS}|$
Output Short Circuit Current .... Continuous
Current at Input Pins .... ±2 mA
Current at Output and Supply Pins .... ±10 mA
Storage Temperature.............................. -65°C to +150°C
Ambient Temp. with power applied .... -55°C to +125°C
ESD protection on all pins .... ≥ 6 kV HBM, ≥ 400V MM
Maximum Junction Temperature (T_J) .... +150°C

†Notice: Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

Electrical Specifications: Unless otherwise specified, all parameters apply for T_A = -40°C to +85°C, V_{DD} = +5.0V, V_{SS} = 0V, $V_{IN}+ = V_{IN}- = V_{REF}/2$. All ppm units use 2^*V_{REF} as full-scale range.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Analog Inputs						
Differential Input Range		—	±2.048/PGA	—	V	$V_{IN} = V_{IN}+ - V_{IN}-$
Common-Mode Voltage Range (absolute) (Note 1)		V_{SS}-0.3	—	V_{DD}+0.3	V	
Differential Input Impedance (Note 2)	Z_{IND} (f)	—	2.25/PGA	—	MΩ	During normal mode operation
Common Mode input Impedance	Z_{INC} (f)	—	25	—	MΩ	PGA = 1, 2, 4, 8
System Performance						
Resolution and No Missing Codes (Note 8)		12	—	—	Bits	DR = 240 SPS
		14	—	—	Bits	DR = 60 SPS
		16	—	—	Bits	DR = 15 SPS
Data Rate (Note 3)	DR	176	240	328	SPS	S1,S0 = '00', (12 bits mode)
		44	60	82	SPS	S1,S0 = '01', (14 bits mode)
		11	15	20.5	SPS	S1,S0 = '10', (16 bits mode)
Output Noise		—	2.5	—	μV_{RMS}	T_A = 25°C, DR = 15 SPS, PGA = 1, V_{IN} = 0
Integral Nonlinearity (Note 4)	INL	—	10	—	ppm of FSR	DR = 15 SPS (Note 6)
Internal Reference Voltage	V_{REF}	—	2.048	—	V	
Gain Error (Note 5)		—	0.1	—	%	PGA = 1, DR = 15 SPS
PGA Gain Error Match (Note 5)		—	0.1	—	%	Between any 2 PGA gains
Gain Error Drift (Note 5)		—	15	—	ppm/°C	PGA=1, DR = 15 SPS

B.6 LCD GDM1602K

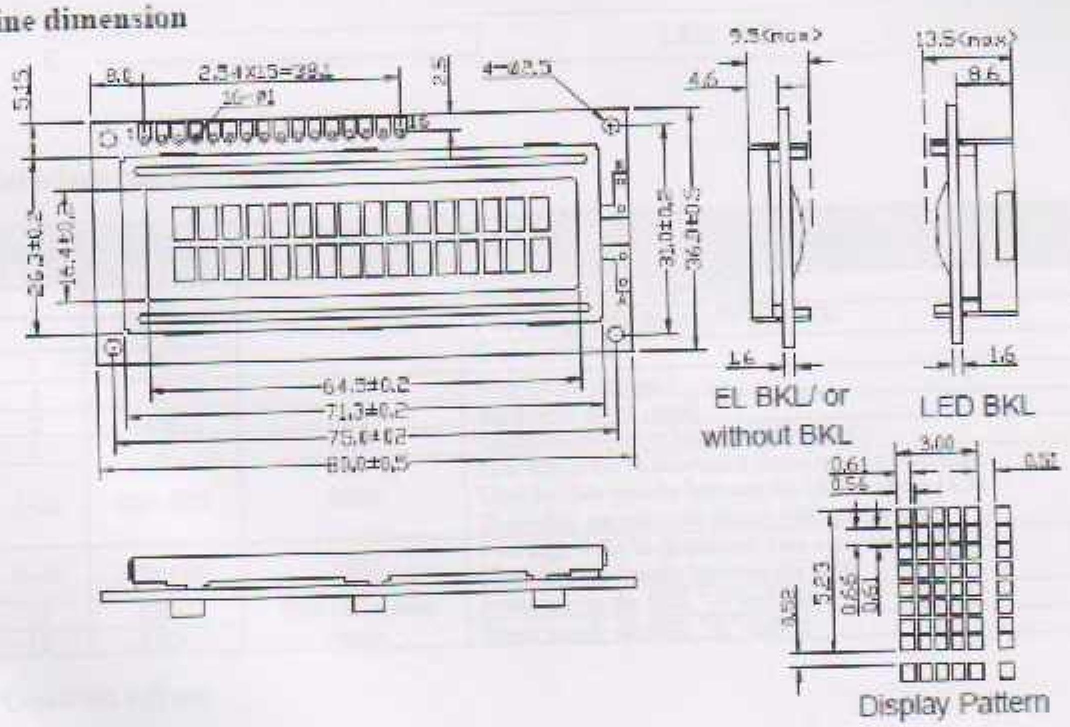
GDM1602K

SPECIFICATIONS OF LCD MODULE

Features

1. 5x8 dots with cursor
2. Built-in controller (KS0066U or equivalent)
3. Easy interface with 4-bit or 8-bit MPU
4. +5V power supply (also available for =3.0V)
5. 1/16 duty cycle
6. N.V. optional
7. BKL to be driven by pin1, pin2, or pin15, pin16 or A, K

Outline dimension

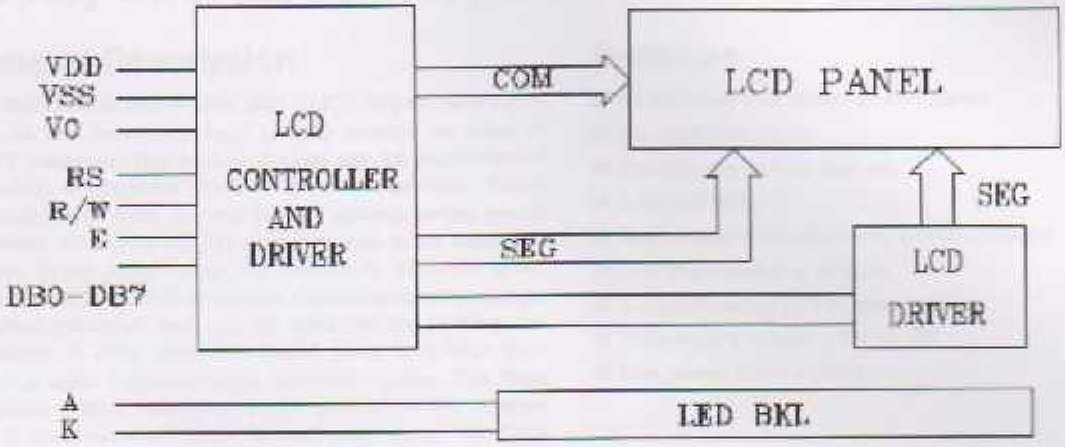


Absolute maximum ratings

Item	Symbol	Standard			Unit
Power voltage	V_{DD}-V_{SS}	0	-	7.0	V
Input voltage	VIN	VSS	-	VDD	
Operating temperature range	VOP	0	-	+50	℃
Storage temperature range	VST	-20	-	+60	

GDM1602K

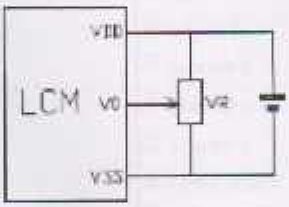
Block diagram



Interface pin description

Pin no.	Symbol	External connection	Function
1	V_{SS}	Power supply	Signal ground for LCM (GND)
2	V_{DD}		Power supply for logic (+5V) for LCM
3	V_0		Contrast adjust
4	RS	MPU	Register select signal
5	R/W	MPU	Read/write select signal
6	E	MPU	Operation (data read/write) enable signal
7~10	DB0~DB3	MPU	Four low order bi-directional three-state data bus lines. Used for data transfer between the MPU and the LCM. These four are not used during 4-bit operation.
11~14	DB4~DB7	MPU	Four high order bi-directional three-state data bus lines. Used for data transfer between the MPU
15	LED+	LED BKL power supply	Power supply for BKL "A" (+4.2V)
16	LED-		Power supply for BKL "K" (GND)

Contrast adjust



V_{DD}-V_0: LCD Driving voltage
VR: 10k~20k

B.7 MM74C923 20-key Encoder

MM74C922 • MM74C923
16-Key Encoder • 20-Key Encoder

General Description

The MM74C922 and MM74C923 CMOS key encoders provide all the necessary logic to fully encode an array of SPST switches. The keyboard scan can be implemented by either an external clock or external capacitor. These encoders also have on-chip pull-up devices which permit switches with up to 50 kΩ on resistance to be used. No diodes in the switch array are needed to eliminate ghost switches. The internal debounce circuit needs only a single external capacitor and can be defeated by omitting the capacitor. A Data Available output goes to a high level when a valid keyboard entry has been made. The Data Available output returns to a low level when the entered key is released, even if another key is depressed. The Data Available will return high to indicate acceptance of the new key after a normal debounce period; this two-key roll-over is provided between any two switches.

An internal register remembers the last key pressed even after the key is released. The 3-STATE outputs provide for easy expansion and bus operation and are LPTTL compatible.

Features

- 50 kΩ maximum switch on resistance
- On or off chip clock
- On-chip row pull-up devices
- 2 key roll-over
- Keybounce elimination with single capacitor
- Last key register at outputs
- 3-STATE output LPTTL compatible
- Wide supply range: 3V to 15V
- Low power consumption

Ordering Code:

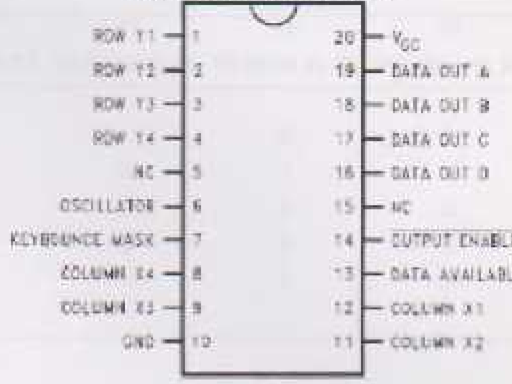
Order Number	Package Number	Package Description
MM74C922WM	M20B	20-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-013, 0.300" Wide
MM74C922N	N18B	18-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide
MM74C923WM	M20B	20-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-013, 0.300" Wide
MM74C923N	N20A	20-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300 Wide

Device also available in Tape and Reel. Specify by appending suffix letter "X" to the ordering code.

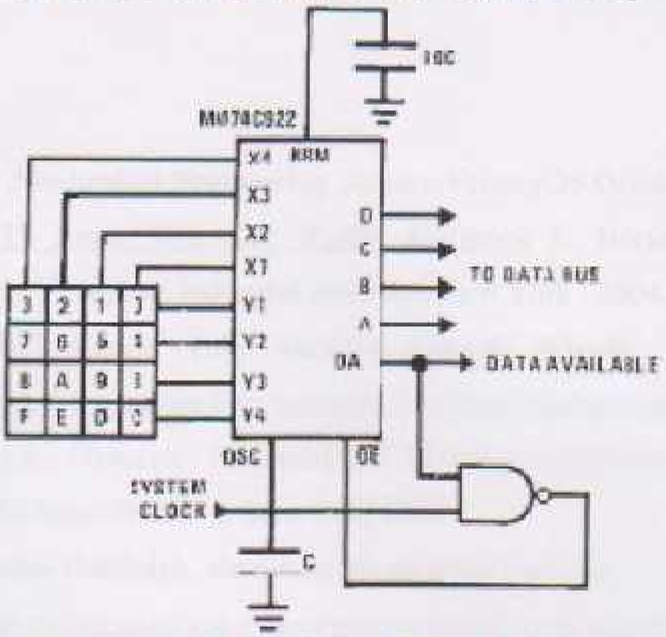
Connection Diagrams

Pin Assignment for DIP

Pin Assignment for SOIC



Synchronous Data Entry Onto Bus (MM74C922)



Outputs are enabled when valid entry is made and go into 3 STATE when key is released.

The keyboard may be synchronously scanned by omitting the capacitor at osc. and driving osc. directly if the system clock rate is lower than 10 kHz

Truth Tables

(Pins 0 through 11)

	Switch Position	0 Y1, X1	1 Y1, X2	2 Y1, X3	3 Y1, X4	4 Y2, X1	5 Y2, X2	6 Y2, X3	7 Y2, X4	8 Y3, X1	9 Y3, X2	10 Y3, X3	11 Y3, X4
D													
A	A	0	1	0	1	0	1	0	1	0	1	0	1
T	B	0	0	1	1	0	0	1	1	0	0	1	1
A	C	0	0	0	0	1	1	1	1	0	0	0	0
O	D	0	0	0	0	0	0	0	0	1	1	1	1
U	E (Note 1)	0	0	0	0	0	0	0	0	0	0	0	0
T													

(Pins 12 through 19)

	Switch Position	12 Y4, X1	13 Y4, X2	14 Y4, X3	15 Y4, X4	16 Y5(Note 1), X1	17 Y5 (Note 1), X2	18 Y5 (Note 1), X3	19 Y5 (Note 1), X4
D									
A	A	0	1	0	1	0	1	0	1
T	B	0	0	1	1	0	0	1	1
A	C	1	1	1	1	0	0	0	0
O	D	1	1	1	1	0	0	0	0
U	E (Note 1)	0	0	0	0	1	1	1	1
T									

Note 1: Omit for MM74C922

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