DESIGN AND DEVELOPMENT OF AUTOMATIC SELF BALANCING SCALE

ERICK BALAN MICHAEL

A report submitted in partial fulfill the requirements for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
University Malaysia Pahang

NOVEMBER 2007

ABTRACT

Every living thing on the planet is affected by weights and measures in some way of form. From the moment we are born and throughout our daily lives, weighing and measuring are an important and often vital part of our existence. Our bodies, the food we eat and all the products we use as an integral part of modern living have all been weighed and measured at some stage in their development. Weights and measures are undoubtedly one of man's greatest and most important inventions, ranking alongside the wheel in the evolution of civilization. Commerce would not have progressed beyond the barter system without the invention of a system of weights and measures. One of the earliest instruments used by human was balance. Balance is an instrument for comparing the weights of two bodies, usually for scientific purposes, to determine the difference in mass. With the help of technology development, there has been improvement to the weighing instruments available today. Therefore, this project deals with an automatic self balancing scale which regards with the instrument for comparing the weight of two bodies. An automatic self-balancing is a weighing operation which is controlled by PC controller in an open loop configuration. It requires power amplification, or the power gain to control the amount of power the motor will be given. This project aims for remote control capabilities so that the self balancing scale can balance itself automatically.

ABSTRAK

Setiap benda hidup di bumi ini dipengaruhi oleh berat dan disukat dengan cara-caranya tersendiri. Pada saat kita dilahirkan dan kehidupan seharian, kewujudan berat dan sukatan memainkan peranan yang penting dalam hidup. Berat badan, makanan yang diambil dan semua produk-produk yang digunakan telah pun disukat beratnya. Tidak disangkal lagi bahawa berat dan sukatan merupakan rekaan manusia yang terhebat. Bidang jual beli tidak mungkin berlaku, seperti pada zaman sistem barter yang telah lama wujud di muka bumi ini. Penimbang merupakan satu alat digunakan untuk menimbang dan membandingkan jisim dan berat diantara dua objek. Biasanya tujuan menimbang adalah untuk tujuan saintifik dan perbandingan antara dua objek. Dengan wujudnya peredaran dan kemajuan teknologi, alat-alat penimbang telah mengalami perubahan dan kemajuan dari aspek penggunaan dan menjadi semakin mudah. Oleh demikian, projek ini bertujuan untuk menghasilkan dan mengkaji alat penimbang yang beroperasi secara automatik. Alat penimbang automatik ini beroperasi dengan sistem kawalan komputer. Projek ini mempamerkan alat penimbang yang mampu mengimbangkan berat di antara dua bahan secara automatik tanpa di kawal oleh pengguna.

TABLES OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

cm	-	Centimeter
mm	-	Milimeter
‘+’	-	Positive Current Flow
‘-‘	-	Negative Current Flow
V	-	Voltage
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
X	-	Multiple
/	-	Divide
Kg	-	Kilograms
G	-	Grams
%	-	Percentage

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCION

Every living thing on our plant is affected by weights and measures in some way of form. From the moment we are born and throughout our daily lives, weighing and measuring are an important and often vital part of our existence. Our bodies, the food we eat and all the products we use as an integral part of modern living have all been weighed and measured at some stage in their development.

Weights and measures are undoubtedly one of man's greatest and most important inventions, ranking alongside the wheel in the evolution of civilization. Commerce would not have progressed beyond the barter system without the invention of a system of weights and measures. One of the earliest instruments used by human was balance. Balance is an instrument for comparing the weights of two bodies, usually for scientific purposes, to determine the difference in mass (Britannica Encyclopedia).

A variation of balance comes with weighing scale which is use for commercial application later. A weighing scale is a device for measuring the weight of an object. These scales are often used to measure the weight of a person, and are also used in science to obtain the mass of an object, and in many industrial and commercial applications to determine the weight of things ranging from feathers to loaded tractor-trailers.

The development of technology has then introduced control system in balancing use. The application of control system to balances instrument makes the world easier for business and commercial use. Control system has been used in different forms for thousands of years. Over the years, an increased number of uses for control have been developed and with ever improving technology it seems the possibilities in the future are only limited by one's imagination. Control system can be found all around us.

The development of automatic control began in 1979 by James Watt when he invented the fly-ball governor (British Crown Copyright, Science Museum,London). From that time, many different systems have emerged as being fundamentally control based something that has a primary function which demonstrates the concept of automatic control. Of these is a stabilizer. As stated by Nise (Fourth Edition, 2004), the four main reasons for building control system are:

1.) Power amplification
2.) Remote Control
3.) Convenience of input form
4.) Compensation for disturbance

An automatic self-balancing is a weighing operation which is controlled by the physical balance function through an open loop system. The application for a control system for the self balancing scale will make full use of the four reasons mentioned above. It requires power amplification, or the power gain to control the amount of power the motor will be given. This project aims for remote control capabilities so that the self balancing scale can balance itself automatically. The main input of the control system is the weights given on the other end of the beam, while the desired output from the system is the distance travelled by the counterweight.

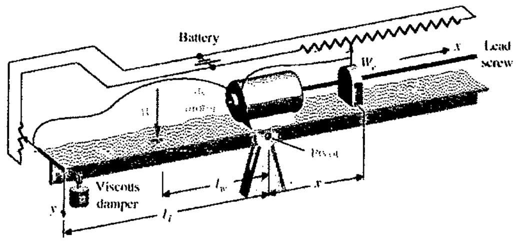

Figure 1.1: Automatic self balancing scale, Z. Jane Wang, University Of British Columbia

1.2 PROJECT PROBLEM

Throughout the ages, weighing instruments have been use in society, either for business or daily uses. The previous invented weighing instruments show the weaknesses of the manual weighing system. Therefore, this project deals with automation of weighing balance with the use of Stepper Motor, Pc interfacing with parallel port and C++ programming. There are three issues in manual weighing system as described below.

1. Although equilibrium of weighing balance can be determine by users manually, its center of balance may differ every time reading is taken. During the translation of counterweight, users determine the center of balance by approximation with using human sense and experiences. Therefore, manual weighing balance shows inaccurate results as the counterweight positioned away from the center of balance.

2. The imbalance of weighing instrument can be balance by adjusting the counterweight over the apparatus until it reach equilibrium position. However, the adjustment of the whole balance is done manually by users.

3. In general, it takes a considerable amount of time for the counterweight to be adjusted for equilibrium. Therefore, main problem with manual weighing instrument is that, it is time consuming. The procedure of measurement, calculation, and adjustment of the counterweight for conventional balance takes time. Users, however, would like to have immediate and complete balance without having time consuming. This is important in industrial use.

The purpose of this project is focusing on control system of the automatic self balancing scale so that the weaknesses of the manual weighing system are solved.

1.3 OBJECTIVE

The existing balance shows some weaknesses. There are three purpose of this project in order to solve the problem with the existing balance. The objectives of the project are:

1. To design an automatic self balancing scale apparatus having a compact structure, capable of adjusting balance in automatic and essential prompt manner, preventing arms from moving so substantially in unbalanced condition.

2. To analysis automation control for the automatic self-balancing scale. It featured Stepper Motor with Parallel Port interfacing for weighing operation which allows the beam to remain in stable when an input (weights) is inserted.

3. To build a prototype of automatic self-balancing scale with the used of machinery tools.

1.4 SCOPE

In order to develop an automatic self-balancing with the use of digital Parallel Port for Stepper motor weighing operation, this project takes into account the consideration of the following scopes:

1. This project use digital PC controller as the control element. While other advanced controller such as fuzzy logic, feed-forward and artificial neural network can as well solve the problem stated, they are not considered for this project.

2. The range of weight to be measured is only in the range of 50g to 500g. The range is for simple application and not to the extend of extreme weight measurement such as small weight use in chemical or large weight use for measure heavy duty objects.

3. This project is only for experimental use, and not for commercial. The prototype is for verify the behavior of the digital PC controller on the weighing operation.

4. The Stepper motor use for simple weighing operation. The developed controller is not intended for heavy duty operation such as crank balance. The experimental setup is for low power application only.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will explain about the previous existing balance throughout the world. It shall feature the history of balance since Mesopotamia and Egypt until the recent development of balance. Balance and weight has affected the world growth in economic since ages ago. It is important to undertake a critical analysis of the work already done and the theory involved. Other recent advances in relevant areas must also be considered, along with well accepted traditional theory and principles associated with the proposal design. It also introduces the possible device use for the new design of automatic self balancing scale such as the application of parallel port for data transfer, stepper motor behavior, and the recommended integrated circuit use with stepper motor.

2.2 The History of Weighing

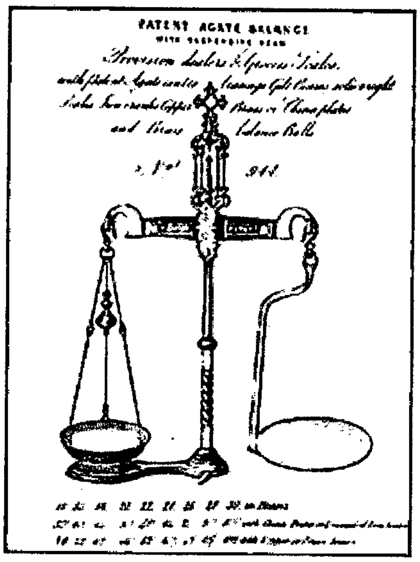

Figure 2.1: Picture of balance, The Avery Historical Museum

Every human being on our planet is affected by weights and measures in some way. From the moment we are born and throughout our daily lives, weighing and measuring are an important and often vital part of our existence. Our bodies, the food we eat and all the products we use as an integral part of modern living have all been weighed and measured at some stage in their development.

Weights and measures are undoubtedly one of man's greatest and most important inventions, ranking alongside the wheel in the evolution of civilization (**fig.2.1**). Commerce would not have progressed beyond the barter system without the invention of a system of weights and measures.

There are three elements to the weighing story and each evolved over the 6,000 years of its history; first, the use and development of weights, then the different weighing machines and apparatus, and finally the introduction of weights and measures to control commercial transactions.

From the time of Egyptian civilization the weights used were made from bronze and often cast in the shape of animals, some in the shape of a cow, which was an ancient standard of value. This customer of making weights in the shape of animals and other decorative designs was practiced in Africa, India and the Far East using brass. Many other materials were used throughout the ages, including porcelain and pottery.

However, the first weights were not introduced by man but by **nature**. In order to weigh small amounts precisely, small objects that were easily obtained and of a consistent size were needed. So the grains and seeds of plants were chosen for their elegant uniformity. A grain of wheat became the grain of weight. Mustard seeds were used to weigh gold in India. The seeds of the liquorices plant and of the carob tree were also used. The carob gave us carats, still used today to express the value of gold and diamonds. The weights of seeds were eventually transformed into stone equivalents for the weighing of general goods, but other materials such as lead were used as well.

2.3 WEIGHING UNITS

Every measuring item requires units in their measurement, and also with weighing unit. From the ancient times, there are few kinds of units were used in measuring weight, which are still use until today. The Romans gave the pound weight which is derived from the Roman word Libra. This explains why the pound unit has such a strange abbreviation (lb) and why the astrological sign Libra has an equal-armed balance as its symbol.

In England there were, at one time, six different pound weights varying from 5,400 to 7,680 grains. Different pounds were used to weigh different commodities such as coins, gold or wool. Henry VIII began the task of standardizing the pound and Elizabeth I completed the work by dividing it into sixteen ounces which totaled 7,000 grains. The Roman pound (or Libra) was divided into twelve uncials, from which we derive our ounces and is referred to as the Troy system. The new Elizabethan pound with its sixteen ounces, known as avoirdupois, was used to weigh general goods, while the twelve ounce pound was reserved for weighing precious metals.

Advances in science are dependent upon accuracy. Every experiment requires superfine measurement so that it can be repeated anywhere in the world and its results independently verified. The problem for eighteenth century scientists was that no common system of measurement existed.

Therefore, in the year 1789, France had her revolution and the ensuing explosion of new thinking led to the development of revolutionary new system of measurement in which all the different physical properties were linked by interrelated units which are called the metric system. Imagine a hollow cube with sides measuring one tenth of a metre. Fill it with water and the volume of that water becomes one liter whilst its weight becomes one kilogram. The master kilogram, made from platinum, resides in Paris, whilst faithful copies, or witnesses, are held in major cities around the world, ensuring that a kilogram weighs exactly the same from Kilmarnock to Karachi. The kilogram units were then used widely throughout the world as a weigh measuring units.

2.4 WEIGHING INSTRUMENTS DEVELOPMENT

The earliest known weighing machine was probably derived from the yoke, whereby it was discovered that two equal masses would balance if they were suspended from a beam that was supported at its centre. Balances were in use in **Mesopotamia** as early as 4000 years BC. They consisted of straight pieces of wood suspended by a cord passing through the centre. Holes, pierced in the ends of the beam, carried cords suspending the scale pans. The accuracy of the beam scale, or balance, relies on ensuring that the distance from the fulcrum to each end of the beam is exactly equal. The disadvantage of this system is that the holes were difficult to locate precisely and the cords moved about in the holes, so affecting accuracy.

More than two thousand years later, the ancient Egyptians refined and improved the balance by simply bringing the cords out of the ends of the beam. A little scraping ensured that the arms always remained equal and the cores always lay against the ends of the beam no matter how heavy the load. This era of **Egyptians refinement** was then bringing to a new development in weighing measurement.

The Greeks and Romans used balances struck from metal, usually bronze, with ring-and-hole pivots - a system that made them less accurate than the better Egyptian balances because of the tendency of the ring to wander in the hole. From the archeologist study, probably the earliest picture of a weighing machine was the Egyptian representation of weighing the souls of the dead against a standard of divine truth. This was discovered in what is believed to be the earliest of religious books, the Egyptian book of the dead. The Egyptian balance survived through the centuries to modern times, and wasn't bettered for more than three thousand years. *(Judgment of the Dead, Marie Parsons)*

The first recorded form of a weighing device other than the balance occurred in 400 BC and was known as the Bismar. It consisted of a rod of wood with a large weight fixed at one end. At the other end was a hook for the goods to be weighed. The user held a rope or metal loop that was slid along the rod until it balanced. The weight was read off a series of notches or nail heads hammered in to the underside of the rod. Somehow, this device wasn't very accurate but traders liked it, probably for the wrong reasons and it became very popular throughout Europe. Aristotle condemned it as an **Instrument of deceit**, but nonetheless it spread across the world under different names. The Normans called it the Auncel, in Russia it was the Bezmen, in India and the Far East it was the Dhari. It was once banned twice in England in the space of a hundred years. Its use did not decline until it was condemned for public weighing by Henry II. However, it is still used today in the Baltic and Eastern European countries and the Far East. *(Avory weight-tronix)*

A new development for weighing measurement was then invented in Rome. The Romans invented the steelyard in 200 BC. The Roman steelyard was another weighing device that has survived to modern times. It consisted of a beam with a sliding poise to counterbalance the load and was generally made from bronze. Although the steelyard offered a practical means of weighing without the use of heavy weights, the balance remained valuable as the most accurate means for weighing precious thing such as gold, certain spices and drugs.

Many instruments were particularly attractive, with the poises often fashioned in the shape of heads of gods, men, women or animals. The steelyard was a cheap, compact and accurate instrument. The Roman principle is still used for the steelyards fitted to modern mechanical platform scales. Large suspended steelyards were in use right up to the end of the eighteenth century for weighing carts. The cart was hoisted clear of the ground by means of chains hanging from the steelyard, some of which were about twenty feet (6m) long.

The first recorded self-indicating scale was designed by Leonardo Da Vinci (1452 - 1519), one of the most remarkable men of time. He produced two designs, one with a triangular chart, and the other semi-circular, but both worked on the same principle. The object to be weighed is placed in a suspended pan. The chart acts as a pendulum and finds a new position of balance. The weight is shown on the chart by a plum bob crossing its face. Like many of Leonardo's conceptions, this scale was ahead of its time was not manufactured until three hundred years after his death.

During Leonardo's lifetime there occurred a further improvement to the accuracy of the balance that is still in use today, which is the development of the Swan Neck Beam, so called because of its shape. Knife-edges were cut into the swan neck ends at right angles to the beam. This enabled the suspension centers of the weighing pans to be accurately located, and provided a true knife-edge, reducing the friction between the knife-edge and suspension ring of the weighing pan.

Prompted by a need for greater accuracy, particularly in the work of alchemists and assayers, inventors in the sixteenth and seventeenth centuries turned their attention to the evolution of the knife-edge as a pivot for the balance. One of the earliest recorded representations of the true knife-edge is the famous portrait by Hans

Holbein the younger of George Gisze, the Hanseatic merchant. Behind the figure, and hanging on the wall, is a beautiful money weighing scale, so accurately drawn that it has been possible to reproduce the actual instrument. Such an instrument could hardly have been a prototype. Therefore there must have been previous efforts in the evolution of this design around the year 1500.

Three triangular knife-edges were incorporated into the later balances. One at the centre of the beam, with its apex pointing downwards, acts as a pivot. The other two at the beam ends with the apexes pointing upwards, from which the scale pans were suspended. Friction between the knife edges and their bearings could still reduce accuracy, so the knife-edges were hardened. Later, a very hard stone was used in their manufacture, and devices to lift the beam clear of the knife-edges when the machine was not in use, were incorporated into balances, to prevent the edges broadening.

In 1857 W & T Avery acquired the rights of Sharkey's patent for a new type of end pivot and bearing for a scale that became known as the brass and agate beam. The rigid construction of the beam, together with the end shackle that housed the agate, gave more protection to the knife-edge against dust and damage. The introduction of this design raised the standard and revolutionized weighing in retail shops.

A Frenchman, Gilles Personne de Roberval. Roberval discovered the 'Static Enigma', that was to defy explanation for the next hundred years. In 1669 he built a model to demonstrate his discovery which comprised a beam, legs and stay, forming a perfect parallelogram. Two arms projected from the legs on which were hung poises of equal weight. His fellow mathematicians were surprised to discover that balance was maintained, even when one poise was moved outwards. No one realized that this was the basis of a scale design, and Roberval's discovery, like Leonardo's was to wait until the nineteenth century before the principle was used to build counter scales. It is still widely used in the manufacture of weighing machines today. The system must retain a perfect parallelogram so that no matter where the load is placed on the platform, or pans, the machine remains in perfect equilibrium. Today,