DESIGN AND CONSTRUCTION OF A PHOTOELECTRIC ENTRY AND EXIT DETECTOR

ONI OLUWABUKOLA FUNKE

2003/15444EE

Department of Electrical and Computer Engineering

Federal University of technology Minna, Niger State

NOVEMBER, 2008

DESIGN AND CONSTRUCTION OF A PHOTOELECTRIC ENTRY AND EXIT DETECTOR

ONI OLUWABUKOLA FUNKE

2003/15444EE

A Thesis Submitted to the

Department of Electrical and

Computer Engineering, Federal University of Technology, Minna, Niger state.

NOVEMBER, 2008

DECLARATION

I, Oni Oluwabukola Funke declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

ONI OLUWABUKOLA FUNKE	MR BALA A.SALIHU
.....	.....
(Name of Student)	(Name of Supervisor)
Funke 10/11/2008	11/11/2008
(Signature and date)	(Signature and date)
DR. Y.A ADEDIRAN	
.....	.....
(Name of H.O.D)	(Name of External Examiner)
.....	.....
(Signature and date)	(Signature and date)

DEDICATION

I appreciate God almighty for making me achieve my education to this point. This project is dedicated to my dad and mum, brother and sister for their support and encouragement.

ACKNOWLEDGEMENT

To my project supervisor, Mr Bala A.Salihu for your efforts in making this project a wonderful experience, thank you sir. Without your constructive criticism, this work would not be what it is. I would also like to acknowledge my Head of Department Dr. Adediran for his encouragement to me an my colleagues, thank you sir. I would also like to thank all the lecturers I've been taught by over the years. To my parents Mr. and Mrs. Adeyinka Oni my gratitude cannot be quantified, thank you for your love and support. without you, I would not even be here. To my brother and sister (Tosin Oni and Toyosi Oni) you are loved. And to my best friends Olanipekun Abayomi Segun and Dada Oluwafunmilayo you guys are the best.

ABSTRACT

This project is a report on the design and construction. It is used to determine the number of people in a room or other enclosure. It has both logistic and security application. For logistics, it can be used to know the number of people in a conference, seminar or other formal gathering so that the number of conference materials (brochures, speeches, programmes of events, refreshments etc) to be produced can be known. For the security aspect, it can be used in banks, supermarkets and museums to ensure that no-one is locked in (either by mistake or intentionally) at closing time. The project is realized using digital circuitry (i.e Integrated Circuits). When the light beams are broken from right to left, the counter increments. When the break is from left to right, the counter decrement. The number showing on the display unit at any point in time is the number of people currently remaining in the enclosure. The project uses latched to clock the Up/Down counters in the circuit and hence determine whether the motion is an entry or an exit.

TABLE OF CONTENT

CONTENT

Title page.....i-ii

Declaration iii

Dedication iv

Acknowledgement.....v

Abstract.....vi

Table of Content.....vii

CHAPTER ONE

1.1 Introduction 1

1.2 Aims and objectives..... 2

1.3 The Scope of Work 3

1.4 Methodology 3

CHAPTER TWO: LITERATURE REVIEW

2.1 History and Development of Counting Devices.....5

2.2 Types of Counters.....8

2.2.1 Asynchronous (Ripple) Counters.....9

2.2.2 Synchronous Counters.....10

2.2.3 Decade Counters.....11

2.2.4 Up/Down Counters..... 12

CHAPTER THREE: DESIGN AND CONSTRUCTION

3.1 Circuit Design 14

3.2 Power Supply Unit.....15

3.3 Infra-Red Generator.....17

3.4 Infra Red Detector 19

3.5 2-Digit Up/Down Counter.....21

3.6 7447 BCD-7 Segment Decoder 23

3.7 Output Load Driver 24

3.8 Display Unit.....25

CHAPTER FOUR: CONSTRUCTION, TESTING AND DISCUSSION RESULTS.

4.1. Circuit Construction 27

4.2 Case Construction 27

4.3 Testing 28

4.4 Result Discussion.....29

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion.....30

5.2 Recommendation 30

REFERENCES 31

CHAPTER ONE

1.1 INTRODUCTION

The world is developing rapidly as a result of technological advancement. In engineering society, the technology has now improved as a result of this improvement, and an emphasis has been placed on digital counters. Digital counters are integrated circuits used for counting events in computers and other digital systems. One common requirement in digital circuits is counting, both forward and backward. Digital clocks and watches are everywhere, timers are found in a range of appliances from micro-wave ovens to VCRs, and counters for other reason are found in everything from automobiles to test equipment. Although we have many variations of the basic counter, they are all fundamentally very similar.

A counter is one of the more useful digital circuits you will encounter. Counters are used in many applications. Examples include frequency dividers, and frequency counters. A quick example of a digital counter would be circuit that drives your stopwatch. This circuit takes at least two inputs, a clock signal from the quartz oscillator, and an input from a button you press. It starts counting when you press the button once, and stops when you press the button again.

Also, a counter is a registered circuit. That is, it has some logic that allows it to store information. It also implies that the counter circuit is a finite state machine (FSM). Therefore, it has several discrete states and these states can only change at the rising and falling-edge of the system clock. For a simple counter, we may have only two states, state

A and state B. In state A, the counter will continue to increment as long as the value of the count is less than the maximum value, it goes into state B, where it is reset to zero and returns to state A. There are several technologies for building individual digital counters. Since counters are available as integrated circuit chips in emitter-coupled logic, transistor-transistor logic, and CMOS.

A discrete - state device(one with only a finite number of output conditions) that respond by advancing to its next output condition. Most digital counters operate in the binary, number system, since binary is easily implemented with electronic circuitry. Binary allows any integer (whole number) to be represented as a series of binary digits, or bits, where each bit is either a 0 or 1 (off or on, low or high, and so forth).

A counter is a device which stores (and sometimes displays) the number of times a particular event or process has occurred, often in relationship to a clock signal. Counters are so important in so many way applications that many different kinds of counter ICs have been designed for both TTL and CMOS logic families.

1.2 AIM AND OBJECTIVES

This is a project that turns on a light when the first person enters a room, and turns off the light when the last person leaves. The main practical applications are:

It is used in the homes, store, office and factory to monitor the number of staff and also serves as security to monitor their movement across the organization.

1.3 THE SCOPE OF WORK

The photoelectric entry and exit detector consist of two photocells (placed only an inch apart) are posted such that a light beam shines on both of them far away from a doorway. When a person enters the room, the first light dependent resistor is shaded first, then second light dependent resistor. When someone leaves the room, the reverse takes place; the second light dependent resistor receives the shadow first followed by first light dependent resistor.

With no one in the room, the readout displays 00 and the load is de-energized. When the first person enters, the display count advances to 01, as more people enter, the count climb while the load will remain active. As people come and go, the readout reflect the changes. When the last person exits, the readouts display 00 and the transistor turns off, and the load is de-energized. The circuit is capable of detecting the presence of 99people and keeping the load activated as long as anyone is in the room.

1.4 METHODOLOGY

The set of methods and principles used in achieving the circuit can be referred to as the top-down methodology. Counting technique is quite interesting and simple in nature. The design holds a light sensor set-up. The energy sources are in line with corresponding light sensor. When the light from the sources is stopped or blocked from reaching the corresponding sensors; there is a count increment or decrement of the machine digital

display unit in respect to the direction of crossing through the two beams. The counting is digitally done through the breaking of light signals in between the light sources and corresponding sensors.

CHAPTER TWO

LITERATURE REVIEW

2.0 HISTORY AND DEVELOPMENT OF COUNTING DEVICES.

Prior to the discovery of alternative means for counting, fingers, toes and stones were used in counting , and in the performance of simple arithmetic calculations such as addition of numbers, subtraction, and so on. This simple way of counting was difficult to use for large counts because stones were very awkward. The use of numbers and counting goes a long way back in time. One of the first methods of counting was Roman Numerals. Today, counting is something we use everyday. Some people use counting to help make the food we eat, while some people use counting to see how many animals are on the earth and in the sea. The abacus device was invented to replace the traditional method (fingers/stones) of counting. The abacus device is an instrument used for counting as far back as 500B.C.Among the countries that used the Abacus were Russia, Japan, China, Greece and Rome. There exist different of Abacus, thus: the Chinese Abacus, Aztec Abacus, Russian Abacus and Japanese device. Around about the year 1200 the Chinese used this method to count. The Aztec, a tribe of Central American Indians used rods stuck into a block of wood, on to which beads were threaded. Other countries like Russia, Japan and China; the beads were threaded on wires held in a wooden frame.

The history of information processing goes back five thousand years to the abacus, one of the earliest known counting devices. This first reported calculator or

processor was developed in ancient Egypt and in Far East during the thirteen century. The abacus consisted of wires strung across a rectangular frame. The frame divides each wire into two sections: The one on the top contains two beads; and the one on the bottom contains five beads. Each top bead represents the quantity 5; each bottom bead represents the quantity 1. Each wire represents a place: units, tens, hundreds, and so on. Computations were done by moving the correct number of beads up to the top of the frame.[1]

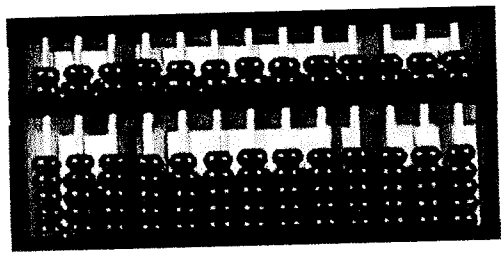


Fig 2.1 An Abacus

The next significant development after the abacus came in 1617 when John Napier, a Scottish mathematician, invented the Napier Bones. These numbers enable the user to easily work out the answers to a restricted set of the multiplication tables. The numbers to be multiplied are positioned on the top row and left column and the answer is obtained at the interoperation of these two. The bones are a set of vertical rectangular rods, each one divided in 10 squares. The top square contains a digit and the remaining squares contains the first 9 multiples of the digit. Each multiple has its digit separated by a diagonal line. When a number is constructed by arranging side by side the rods with the

corresponding digits on the top, then its multiple can be easily obtained by reading the corresponding row of multiples from left to right while adding the digits found in the parallelograms formed by the diagonal lines.

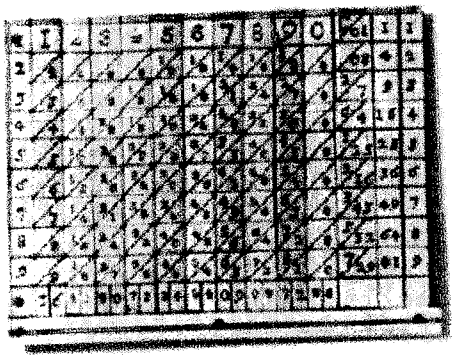


Fig 2.2 Napier's Bones

Counting boards are the earliest known form of a counting device (excluding fingers and the other very simple methods). They were made from natural materials such as stones or wood, and the actual counting was done on the board with beads, pebbles, or even colored sand. Not many of these board survive today because of the perishable materials used in their construction. The oldest known example of a counting board was discovered on the Greek Island of Salamis in 1899. It is thought to have been used by Babylonians in about 300B.C. and is more of a gaming board rather than a calculating device. The gaming boards used by ancient cultures such as the Babylonians and the Romans are thought to be the precursors of the abacus. The Salamis Tablet is approximately 150*75*4.5cm and is made of marble. Parallel grooves and Greek symbols are carved into it.

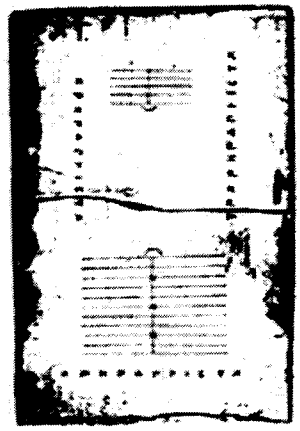


Fig 2.3 The Salamis Tablet

2.2 TYPES OF COUNTERS

Circuits for counting events are frequently used in computers and other digital systems. Since a counter circuit must remember its past states; it has to possess memory. The number of flip-flops used and how they are connected determine the number of states and the sequence of the states that the counter goes through in each complete cycle. They can be implemented quite easily using flip-flops.

Counters can be classified into two broad categories according to the way they are clocked. We have;

[1] asynchronous (ripple) counters - the first flip-flop is clocked by the external clock pulse, and then each successive flip-flop is clocked by the Q or Q' output of the previous flip-flop.

[2]synchronous counters – all memory elements are simultaneously triggered by the same clock.

2.2.1 Asynchronous (ripple) Counters

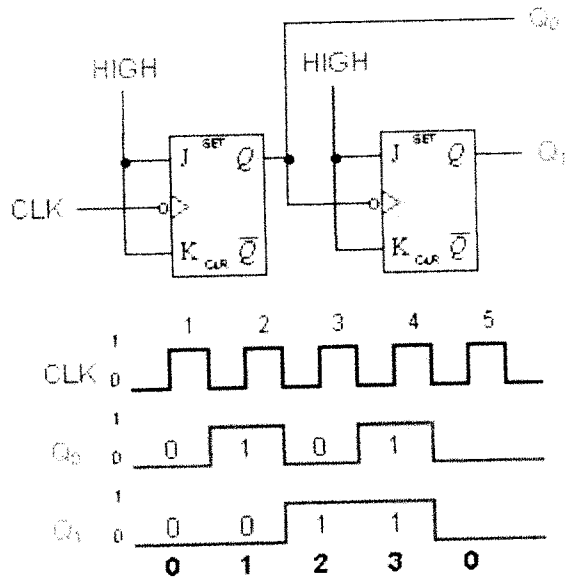


Fig 2.3 Asynchronous (ripple) Counters

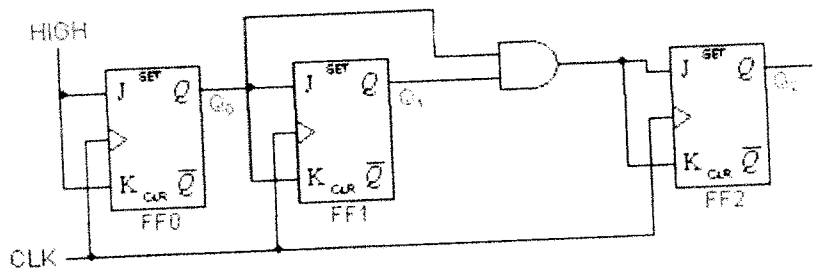
These counters are the simplest type of binary counters, since they require the lowest components to produce a given counting operation. The external clock is connected the clock input of the first flip-flop (FF0) only. So, FF0 changes state at the falling edge of each clock pulse, but FF1 changes only when triggered by the falling edge of the Q output of FF0. Because of the inherent propagation delay through a flip-flop, the transition of the input clock pulse and a transition of the Q output of an FF0 can never occur at the same time. Therefore the flip-flops cannot be triggered simultaneously, producing an asynchronous operation.

Note that for simplicity, the transitions of Q0 , Q1 and CLK in the timing diagram in fig 2.3 are shown as simultaneously, even though this is an asynchronous counter. Actually, there are some small delay between the CLK, Q0, and Q1 transitions. Usually all the CLEAR inputs are connected together, so that a single pulse can clear all the flip-flop

before counting starts. The clock pulse fed into FF0 is rippled through the other counters after propagation delay, like a ripple on water, hence the name RIPPLE COUNTER.

2.2.2 Synchronous Counters

The clock inputs of all flip-flops are connected together and are triggered by the input pulses. Thus, all the flip-flops change state simultaneously (in parallel). The circuit below is a 3-bit synchronous counter. The J and K inputs of FF0 are connected to HIGH. FF1 has its J and K inputs connected to the output of FF0, and the J and K inputs of FF2 are connected to the output of an AND gate that is fed by the outputs of FF0 and FF1. At the 3rd clock pulse, both outputs of FF0 and FF1 are high.[5]



The most important advantage of synchronous counters is that there is no cumulative time delay because all flip-flops are triggered in parallel. Thus, the maximum

operating frequency for this counter will be significantly higher than the corresponding ripple counter.

2.2.3 Decade Counters

Decade counters are designed to have the number of states in their sequences, which are called truncated sequences. These sequences are achieved by forcing the counter to recycle before going through all of its normal states. A common modules for counters with truncated sequences is ten. Once the counters counts ten (1010), all the flip-flops are being cleared while Q1 and Q3 are used to count ten.

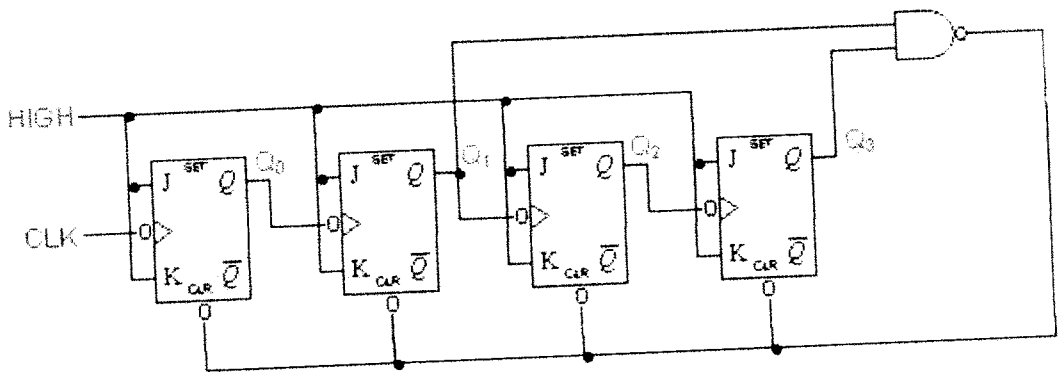


Fig 2.5 Decade Counter

2.2.4 Up-Down Counters

Up-Down counters counts up or down depending on the status of the control signals UP and DOWN. When the UP input is at 1 and the DOWN input is at 0, NAND network between FF0 and FF1 will gate the non-inverted output (Q) of FF0 into the clock input of FF1. Similarly, Q of FF1 will be gated through the other NAND network into the clock input of FF2. Thus, the counter will count up.

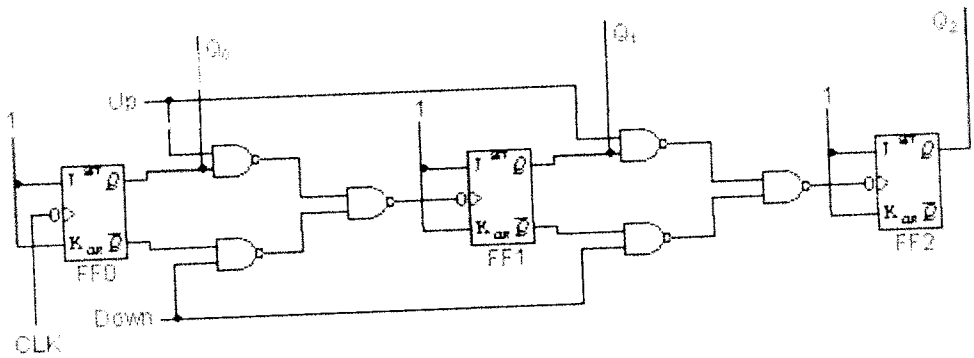


Fig 2.6 Up-Down Counter

When the control input Up is at 0 and Down is at 1, the inverted outputs of FF0 and FF1 are gated into the clock inputs of FF1 and FF2 respectively. Up-Down counter is slower than an Up counter or a Down counter because of the propagation delay introduced by the NAND networks.

The counter in use in this project is

1. Synchronous because it is required that the counters increment or decrement at the same time.
2. Up-Down because it is required for the circuit to be able to count both up and down.
3. Decade because it is required for the counter to overflow after 10 inputs have occurred.

CHAPTER THREE

DESIGN ANALYSIS

3.1 CIRCUIT DESIGN

The photoelectric entry and exit detector comprises of the following sub-system

1. Power supply Unit
2. Infra-Red Generator
3. Infra-Red Detector
4. 2- Digit Up-Down Counter
5. 7447 BCD – 7 Segment Decoder
6. Display Unit.

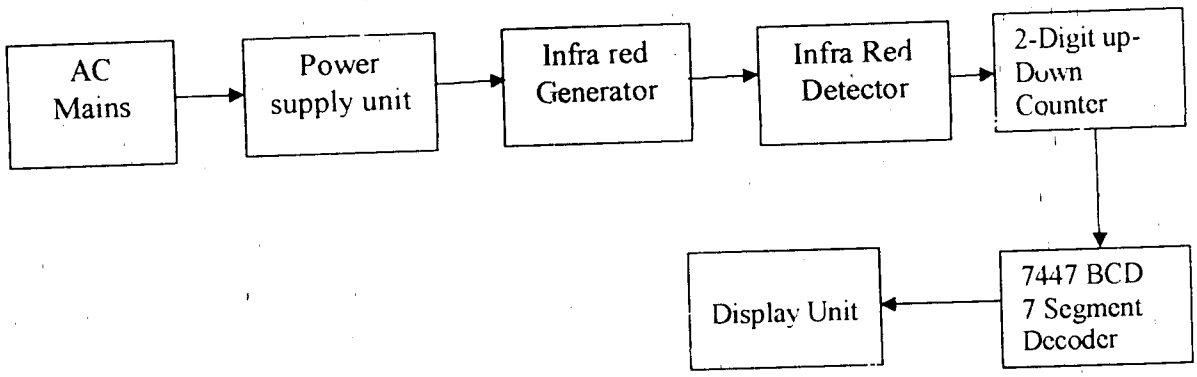


Fig 3.1 Block diagram

3.2 POWER SUPPLY UNIT

A regulated D.C output is one terminal whose voltage remains almost constant regardless of the amount of current drawn from it.

A regulated 5 volt DC supply was required for the system. This was derived from a 12V 1A step down transformer and a full ware rectifier as shown below

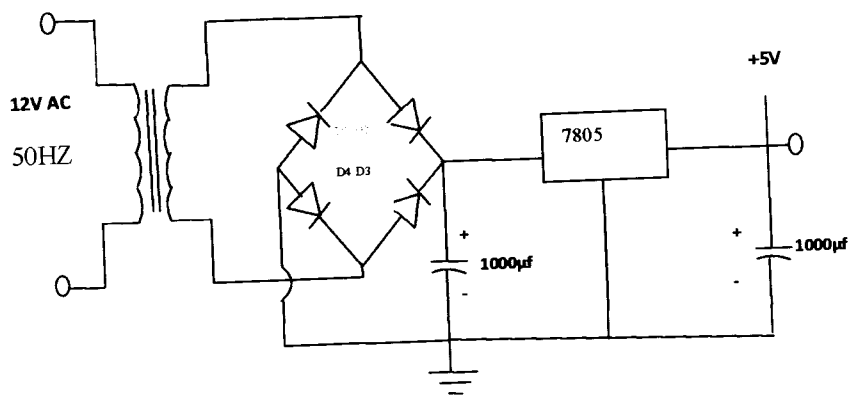


Fig 3.2Power Supply Unit

The 12VAC input voltage was converted to a pulsating DC of amplitude given by the expression:

$$V(peak) = 12\sqrt{2} - 14.2 \cong 15.5V$$

This DC voltage was smoothened by a capacitance deduced from the formula: $C = \frac{It}{V}$

Where I = Maximum load current

$$T = \tfrac{1}{2} f = \frac{1}{2A} \times 50$$

V = Peak - Peak AC ripple voltage

The load current was computed from the total summation of the current drawn by the different sub-systems.

Infra – Red Generators - 50mA

Infra – Red Detector - 50mA

Counter _____5mA

Display _____ $\cong$ 400mA

$\Sigma I \cong 500MA$

For a regulated 5 volt output, the minimum input voltage in the regulator was 7V (taken from manufacturer Specs sheet)

On a 15.5V pulsating Dc voltage, the Peak – Peak Ac ripple voltage is thus:

$$15.5 - 7 = 8.5V$$

Introducing the above parameters into the expression for the calculation of C yields:

$$C = \frac{0.5 \times \frac{1}{2 \times 50}}{8.5}$$

$$C = \frac{0.005}{8.5}$$

$$C \cong 600\mu f$$

This value is the minimum required to meet the worst – case system requirements. It was increased to 1000μF for improved system performance.

The 5 – volt output was stabilized by a 1000μF capacitance and fed into the circuit.

3.3 Infra – Red Generator

To generate the required IR beam needed for detecting entrance and exit motion, a source of 38KHz IR energy was required. This was realized using an NE555 device configured as a 50% only cycle as table oscillator as illustrated below

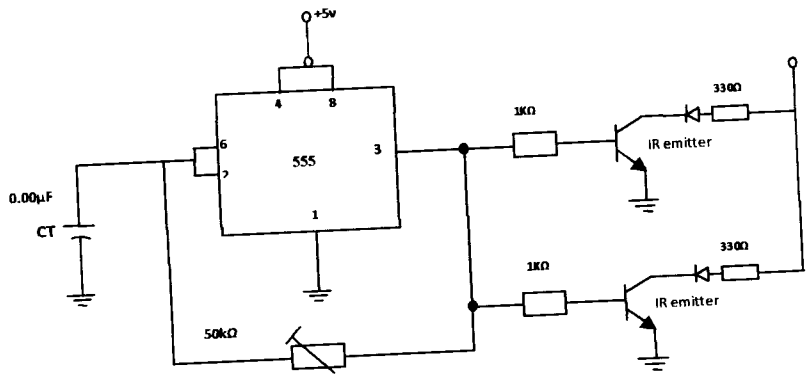


Fig 3.3 IR generator Generator

The output frequency of the oscillator is approximately given by the expression.

$$F = \frac{1}{2\pi R_T C_T}$$

R_T is the resistance between the output and pin 6,2.

C_T is the capacitance from pins 6, R to ground.

The output waveform is a $38KH_2$ 50% duty cycle square ware. The output frequency was fed into the base emitter junctions of two C9014 transistors as show in fig 3. Two IR emitting diodes were placed in the collector – emitter circuit of each transistor.

A current – limiting resistances of values deduced from the expression below were connected on series with each diode to limit the current to a safe level.

$$Rs = \frac{Vs - V_{LED}}{I_{LED}}$$

$Vs = +5V$, $V_{LED}=IV$, $I_{LED} = 12mA$

$$Rs = \frac{5 - 1}{0.012}$$

$Rs = 330K$

The current through the base – emitter circuit was computed from the expression

$$I_B = \frac{Ic}{B}$$

Where B = 200 for the C9014 transistor used

$$I_B = \frac{0.012}{2 \times 10^2}$$

$I_B = 6 \times 10^{-4}$

$I_B = 600mA$

$$R_B = \frac{V_B - V_{BE}}{I_B}$$

V_B = output high voltage level on pin 3 of the 55 device

$$R_B = \frac{5 - 0.7}{6 \times 10^{-4}}$$

$$R_B = \frac{4.3}{6} \times 10^4$$

$$R_B = 70K\Omega$$

The value was reduced to 12KΩ to guarantee adequate IR energy radiated from the emitter diodes.

3.4 INFRA – RED DETECTORS

A pair of IR detector circuit was wired to detect the absence/presence of the radiated IR signal. A commercially available 3 – pin tsop1738 IR sensor were used for this purpose. They were connected to monostables waveform regenerators to recreate logic –level compatible outputs that were fed into the up/down input of the counters.

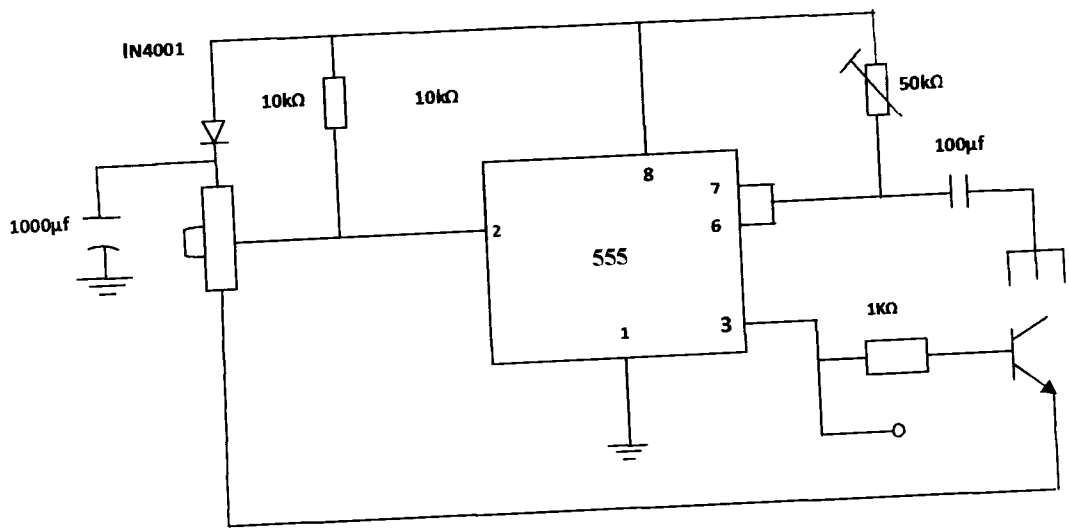


Fig 3.4 IR Detectors

Due to the need to hare only a clock input active at a time, the circuit was arranged such that when a sensor is activated, it correspondingly disables the monostable/sensor combination. This was realized by feeding the active – low reset input on each 555 with the complemented output of the opposite 555 as shown in fig 3.4.

The monostables were arranged to provide an output pulse width of period obtained by the values of R1 and C1. For a 55 monostable, the output pulse width is given by the expression.

$= 1.1\ R_T C_T$

R_T is the resistance between Vce and pins (2,6).

C_T is the capacitance between pin (7,6) and ground.

The IR sensors were connected to pin 3, 2 of the 555 device, configured as a monostables, the device triggers whenever the voltage on pin 2 falls below 1/3 Vcc. On a 5V system supply. This translates into a switching level of 1.67V.

If the sensor is constantly by a constant amplitude IR signal, its output is high.

However, when a beam discount occurs, its output switches low, taking pin 2 of the monostables is $\leq$ 1/3 Vcc, forcing the output pin 3 high and producing a momentary pulse at the output.

3.5 2 – DIGIT UP/DOWN COUNTER

To keep track of entrance /exit motion, a two – digit counter system was realized using 74LS192 synchronous up/down counter.

The counters were cascaded as shown below:

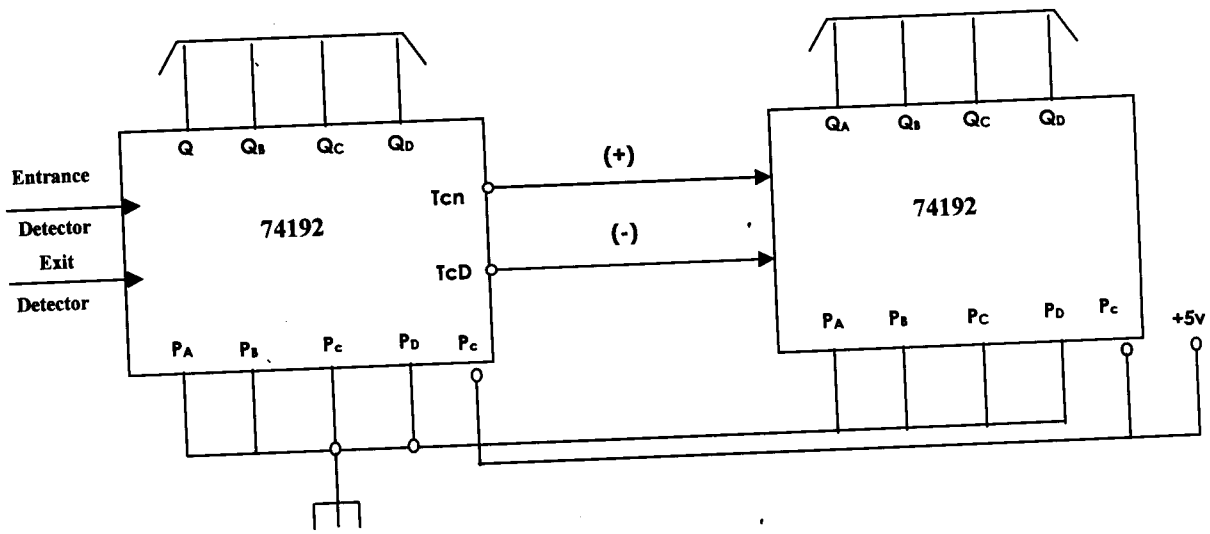


Fig 3.5 2-Digit up/down counter

The LSD (units) counter was driven directly from the monostables. The terms counter was driven from the units counter via the terminal lay up/terminal lay down outputs.

The parallel load logic input were deasserted by tying them to +5V. The 4 – bit BCD output from each counter was fed into a 7447 BCD – 7 segment decoder where they were subsequently converted to 7 – segment code before displaying the corresponding to the occupancy level by the counters.

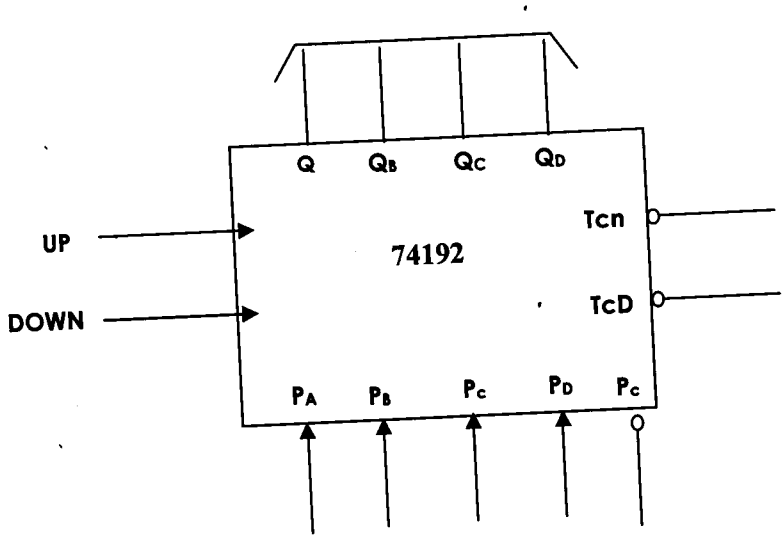


Fig 3.X 74192 Synchronous up/down Counter

3.6 7447 BCD – 7 SEGMENT DECODER

To generate the required segment illumination from the 4 – bit BCD outputs from the counters, a 7447 BCD – 7 segment decoder was used. The 7447 was designed for common – an code 7 – segment displays.

It's input circuits was wired to the counters and its output circuit connected to segments a –dp on the 7 – segment display.

The truth table of the 7557 is given below

BCD Codes	Character Displayed
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9

Table 3.6 BCD coders to corresponding displayed character

3.7 OUTPUT LOAD DRIVER

An LED was used to provide a visual indication of occupancy. The indicator was an LED placed in the collector emitter circuit of an NPN transistor as shown.

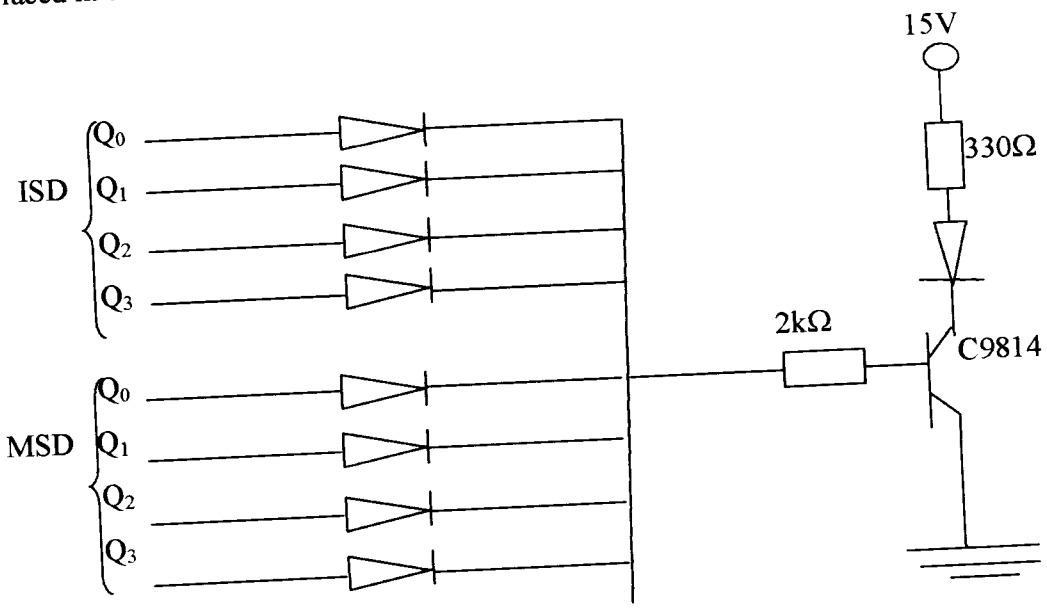


Fig. 3.6 Occupancy Indicator

With the two counters registering zero, the 8 – in or gate formed by the 8 diodes has an output logic level of zero. This cuts the C9014 transistor off, keeping the LED off.

However, when any of the outputs switches high, the transistor is forward – biased and the LED comes on, and glows.

The current through the LED was limited by a resistance of value deduced from the expressions.

$$R_S = \frac{V_S - V_{LED}}{I_{LED}}$$

$$Vs = +5V,\ V_{LED} = 1.7V,\ I_{LED} = 10mA$$

$$Rs = \frac{5 - 1.7}{0.01}$$

$$Rs = 330\Omega$$

3.8 DISPLAY UNIT

The display unit is made up of two up/down BCD counters, corresponding BCD to 7-segmemnt decoders, and large common anode LED 7 – segment displays.

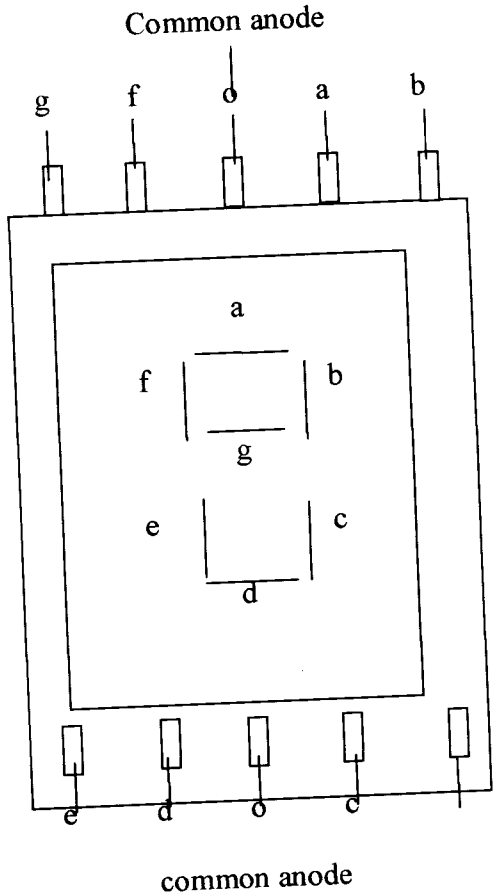
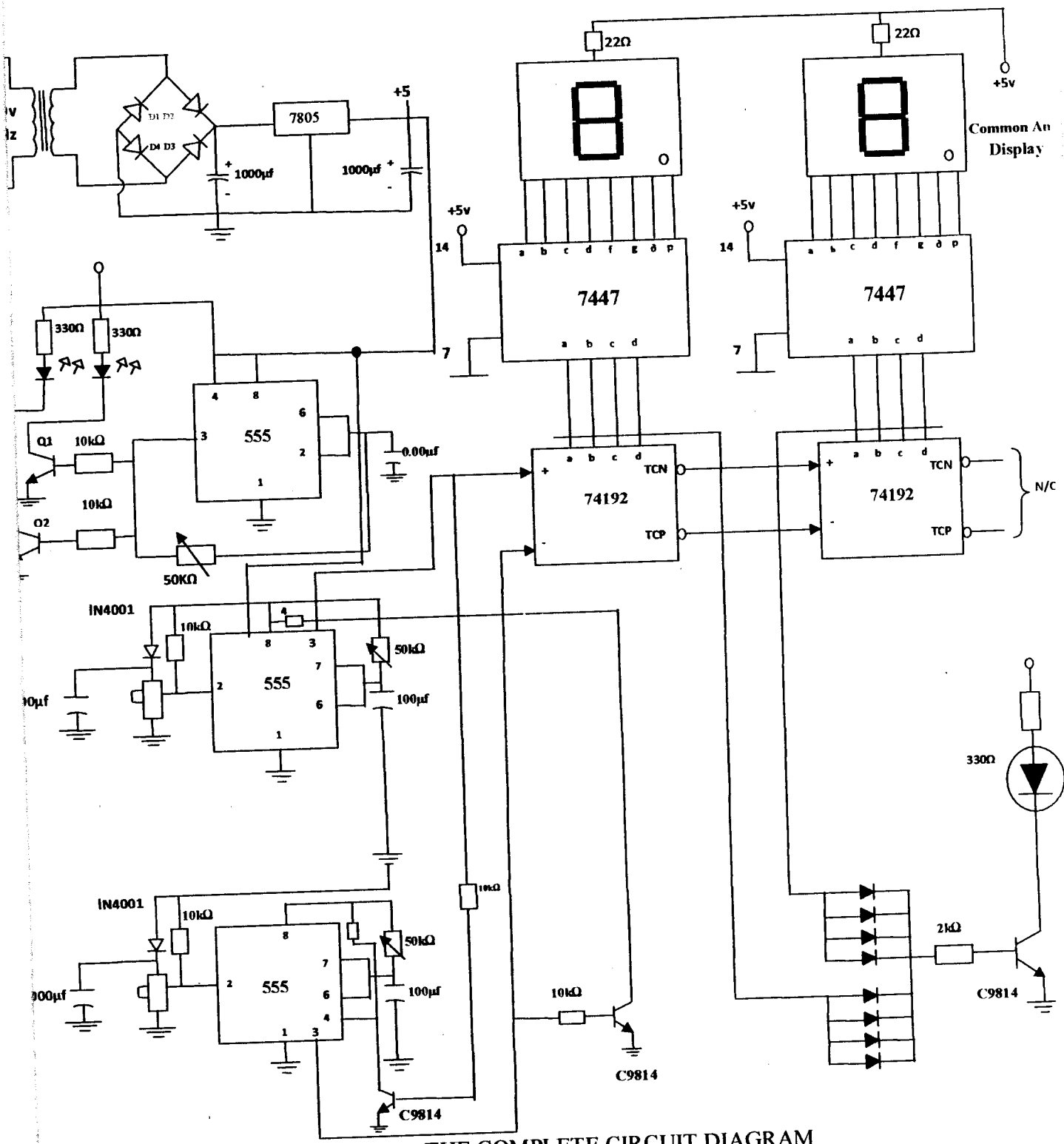


Fig. 3.8 The layout of a common anode 7 – segment LED display



THE COMPLETE CIRCUIT DIAGRAM

CHAPTER FOUR

CONSTRUCTION,TESTING AND DISCUSSION OF RESULTS

4.1 CIRCUIT CONSTRUCTION

The construction part of the project followed the design step. It involved practical exercise in connecting the involved electronic components and parts in accordance with the circuit diagram. The construction was achieved by dividing the total circuit into units. Each unit was executed one after the other, after which the units were joined together as a single working construction.

The power supply unit was of great importance during the construction and it was made with great care. After the complete construction, the power unit was properly checked for short circuit and unwanted bridges. Afterwards, the other parts of the circuit were connected to it.

4.2 CASE CONSTRUCTION

The casing of the constructed circuit was done through the use of stainless steel, plastic and rubber materials. The materials were carefully selected for different parts of the circuit. The set up was quite flexible to allow easy mobility and also the material was covered with shaded nylon to make the displayed digit more visible

4.3 TESTING

The physical realization of the project is very vital. This is where the fantasy of the whole idea meets reality. The designer will see his or her work not just on paper but also as a finished hardware.

After carrying out all the paper design and analysis, the project was implemented and tests were performed on the completed construction so as to check its response and indicators, and this was performed numerous times before a conclusion was made about the project. performance with the aims of the project. The testing basically involved the complete setting up of the circuit and providing input into the sensors by walking across them.

The testing procedures are to display increment and decrement and the directional indicators and this was performed numerous times before a conclusion was made about the project.

4.4 RESULT DISCUSSION

The result was positive. The main feature of device direction detection worked properly. The display counter was incremented when someone crossed the input sensors from the right. The count was decremented with the left crossing.

Whenever pressed, the display reset button was able to put the count to zero. Also the display did not register a half crossing and did not decrement further when the count was '00'.

The only setback occurred when the light beams from the light source were not properly focused on the input sensors. In this situation, the counter may give an erroneous count. This can be remedied, however, by using a stiff, inflexible stand for both the display and the light source stands and bb measuring the distance between both torches more precisely so that they focus exactly on the input sensors.

Also, the project has the limitation that it can only be used in building s with only one entry and exit point. However, it may not really be a problem as this often the case in situations where security is paramount, such as in banks and official functions.

Aside from this, the design was a success.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The project shows the importance of digital electronic in counting applications. Modern electronic components, or sensors to be particular, have extremely flexible features and attachments for numerous purposes that can relate a device with the status of its environment.

The attributed simplicity in construction of the circuit corresponds to the reasonable level of acquired information for the project. In term of the acquisition of information, the internet was a very useful tool for the project.

Moreover, the project provides a real practical experience in electronics and highlights the significance of what was taught in the class.

5.2 RECOMMENDATION

i) The project could be modified with micro-controllers for better features.

ii) Wider counting ranges could be achieved by incorporating more counters, decoders and seven-segment displays into the design.

iii) Talking alarms could be incorporated into the design.

iv) The display could be made of Liquid Crystal Display (LCD) to reduce power consumption.

REFERENCES

[1] Fernandes Luis, A Brief History of the Abacus, 2003

http://www.ee.ryerson.ca: 8080/ elf/abacus/history.

[2] Introduction to Counters

http://www.eelab.usyd.edu.au/digital_tutorial/part2/counter 01.html

[3] George Ifrah, The Universal History of Numbers:From Prehistory to the Invention of the Computer, Wiley, 1999

[4] Article On Counters

http://www.wikipedia.org/search-redirect.php?search=counters&language=en&go=G

[5] Project Work of Oyawoye Motolani 06/2007

[6]Synchronous Binary Counters

http://www.play-hookey.com/digital/synchronous-counter.html

[7] Donald E.Knuth, The Art of Computer Programming, Volume 2, 3rd Ed., Addison-Wesley.pp.194-213, "Positional Number Systems"

[8] Herbert Taub and Donald Schilling, Digital Integrated Electronics, McGraw Hill, 1977, p322, "Registers and Counters"

[9] A.K Theraja and B.L. Theraja, A Textbook of Electrical Technology, 23rd Ed., S Chand & Company,2003, pp.1922-1923