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Design and Implementation of a Four ways or Junction prototype crossroad traffic light control system

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ABSTRACT

This paper is aimed at creating prototype traffic light model using LED (Light Emitting Diode) since LEDs consume 80-90 percent less energy and generally last 5-7 years or longer compared to just a year for a incandescent light signal.LED are brighter, the LED arrays fill the entire “hole” and have equal brightness across the entire surface, making them brighter overall.

It will also involves the use of a digital logic gate, multivibrator, IC (Integrated Circuit), timer for the design and circuit simulation to analysis the system efficiency. This design has for long outweighed the older system in many ways it is more efficient and effective as well, as it can enhance the transportation system of the country saving many hours usually lost in traffic problems. Accidents may also be prevented and lives can be saved and It can be used effectively by implementing in heavily congested areas.

Keyword: Controller, LED (Light Emitting Diode),Prototype, Traffic,

INTRODUCTION

Traffic light which is one of the vital public facilities that plays an important role to the road users. Traffic lights were first installed in 1868 in London, United Kingdom, outside the British Houses of Parliament in London, by the railway engineer J. P. Knight and constructed by the railway signal engineers of Saxby & Farmer. The design combined three semaphore arms with red and green gas lamps for night-time use, on a pillar, operated by a police constable. The gas lantern was turned with a lever at its base so that the appropriate light faced traffic. Although it was said to be successful at controlling traffic, its operational life was brief. It exploded on 2 January 1869, as a result of a leak in one of the gas lines underneath the pavement, injuring and killing the policeman who was operating it. With doubts about its safety, the concept was abandoned until electric signals became available. The first electric traffic light was developed in 1912 by Lester Wire, an American policeman of Salt Lake City, Utah, who also used red-green lights. Mary Bellis (5 February 1952).On 5 August 1914, the American Traffic Signal Company installed a traffic signal system on the corner of East 105th Street and Euclid Avenue in Ohio. It had two colors, red and green, and a buzzer, (based on the design of James Hoge) to provide a warning for color changes. The design by James Hoge allowed police and fire stations to control the signals in case of emergency. The first four-way, three-color traffic light was created by police officer William Potts in Detroit, Michigan in 1920. Moyer, Sheldon (March 1947). In 1922, T.E. Hayes patented his "Combination traffic guide and traffic regulating signal" (Patent #1447659). Ashville, Ohio claims to be the location of the oldest working traffic light in the United States, used at an intersection of public roads until 1982 when it was moved to a local museum (Neato Stuff at the Ashville Museum).The traffic lights consist of a set of three coloured lights: red, yellow and green.(In a typical cycle, Illumination of the green light allows traffic to proceed in the direction denoted, Illumination of the amber/yellow light denoting, if safe to do so, prepare to stop short of the intersection, and Illumination of the red signal prohibits any traffic from proceeding). [1,2]

HISTORY AND EVOLUTION OF TRAFFIC LIGHT SYTEM

Traffic light system consists of two parts, first part is traffic light and the second part is controller unit. Traffic light which is one of vital public facilities plays an important role to the road user, which is used to control traffic flows at the busy intersection.

The world's first traffic light came into being before the automobile was in use, and traffic consisted only of pedestrians, buggies, and wagons. Installed at an intersection in London in 1868, it was a revolving lantern with red and green signals. Red meant stop and green meant caution. The lantern, illuminated by gas, was turned by means of a lever at its base so that the appropriate light faced traffic. On January 2, 1869, this crude traffic light exploded, injuring the policeman who was operating it [3,4].

And with the coming of automobiles, the situation got even worse. Police officer William Potts of Detroit, Michigan, decided to do something about the problem. What he had in mind was figuring out a way to adapt railroad signals for street use. The railroads were already utilizing automatic controls. But railroad traffic travelled along parallel lines. Street traffic travelled at right angles. Potts used red, amber, and green railroad lights and about thirty-seven dollars worth of wire and electrical controls to make the world's first 4-way three colour traffic light. It was installed in 1920 on the corner of Woodward and Michigan Avenues in Detroit. Within a year, Detroit had installed a total of fifteen of the new automatic lights.

At about the same time, Garrett Morgan of the United States realized the need to control the flow of traffic. A gifted inventor and reportedly the first African American to own an automobile in Cleveland, Ohio, he invented the electric automatic traffic light. Though it looked more like the semaphore signals you see at train crossings today, it provided the concept on which modern four-way traffic lights are based.

The First Four way traffic signal was originated by William Potts of the Detroit Police Department and he is generally credited as the originator of the red-yellow-green traffic signal as we know today. His signal, built of wood with metal shell, used four inch railroad lantern-style lenses. The signal, probably of the overhead suspension type, marked another pioneering venture for Detroit when it was installed. He instituted electrical interconnection of the signal of fifteen of Detroit's traffic towers so that they could be controlled by a police officer from a single location.

However ,Light Emitting Diodes (LEDs) Traffic Light which are the new traffic light designs are made out of arrays of light emitting diodes (LEDs). These are tiny, purely electronic lights that are extremely energy efficient and have a very long life. Each LED is about the size of a pencil eraser, so hundreds of them are used together in an array. The LEDs are replacing the old-style incandescent halogen bulbs rated at between 50 and 150 watts.

LED bulbs save a lot of energy. The energy savings of LED lights can be huge. Assume that a traffic light uses 100-watt bulbs today. The light is on 24 hours a day, so it uses 2.4 kilowatt-hours per day. A big city has thousands of intersections, so it can cost millions of dollars just to power all the traffic lights. LED bulbs might consume 15 or 20 watts instead of 100, so the power consumption drops by a factor of five or six. A city can easily save a million dollars a year by replacing all of the bulbs with LED units. These low-energy bulbs also open the possibility of using solar panels instead of running an electrical line, which saves money in remote areas.[5,6,7]

Purpose of Traffic Light

1. Safe and efficient traffic light flow

2. Assign right of way to maximize capacity, minimize and reduce collision and conflict.

Advantage of Traffic Light

i. Minimize conflicting movement

ii. Provide orderly movement of traffic

iii. Provide driver confidence by engaging the right ways

iv. Means of interrupting heavy traffic

v. Coordinated for continuous vehicle movement

Cross Road Traffic Light Control

Crossroads is where two or more roads cross each other and form an intersection. Design and Implementation of Crossroads of Four (4) way traffic light control types will be the main focus of this project. Crossroads vary from the very quiet residential areas to the hectic multi-lane systems is busy areas. Crossroads can cause confusion for not only learner drivers, Pedestrian but experienced fully licensed drivers are often unsure how to deal with them.[8]

Recently the traffic management is trying out new a new system of traffic lights based on the usual international standard. A synchronous digital circuit has to be design, which operates this new type of traffic light for cross road or road crossing.

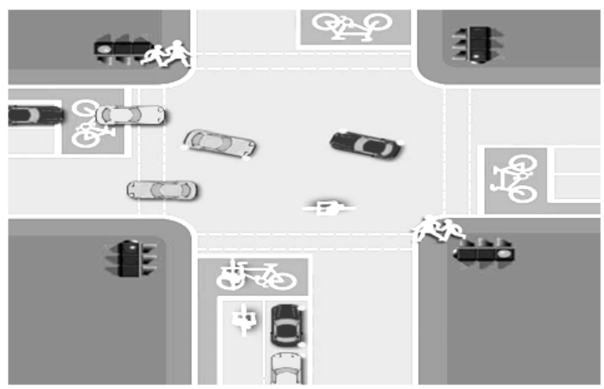

Fig. 1 Cross Road Traffic Control System.

The Cross Road Traffic Light controls will consist of 12 lights to operate. The Red, Amber/Yellow and Green lights R1-R2,A1-A2,G1-G2 in the North-South direction also, the lights in the East-West direction will also consist the Red, Amber/Yellow and Green which could be named as R3-R4, A3-A4,G3-G4 when the digital signals are in the logic state they turn their respective lights on, otherwise the lights are off. There are two types of road crossing: Quiet crossings that use simple sequence and busy crossing require a longer (delayed green) sequence. Some junctions may use the busy sequence during the day and quiet sequence at night.

DESIGN ANALYSIS

The design of a prototype traffic light controller for cross road system is such that utilizes the concept of 4017 Decade counter IC. The pulses from the 555 timer in the Astable multivibrator mode sets the counter, the counter being a Johnson decade counter, as a Decade counter. i.e. each subsequent output will get high on the negative edge of the previous output pin. For example the outputs are from Q0 to Q9, as per the counter, first Q0 will get high. At the moment Q0 gets low, Q1 will start working and so on till Q9.

The design is such that both the 555 timer and the 4017 decade counter are operating from the same source voltage. The design employs the use of 555 timers as the pulse generator and decade counter as the Binary Coded Decimal (BCD). The Design is made up of two functional units, these are:

- The Binary Coded Decimal (BCD)
- The Pulse Generator

Each of these units has sub units (components), which enable in accomplishing the purpose of this project.

The Binary Coded Decimal (BCD) unit consists of:

- The 4017 counter
- Signal Diode
- Resistor

The Pulse Generator unit consists of:

- The 555 timer
- Variable Resistor
- Resistor
- Capacitor

The Output/Displayed Unit

- LED

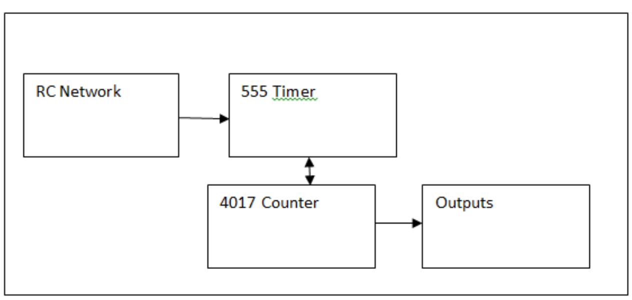

Fig. 2 Block Diagram of the Traffic light controller.

This project combines the elements of both 555 timer and 4017 Decade counter IC.

Pin 1 to pin 7 and pins 8, 9, 10 are all the outputs of the decade counter which gives signal to the North-South LED and East-west LED. Pin 16 serves as positive supply and pin 8 is ground (-).

The pin 15 is the reset point of the IC; grounding of this pin gives a green signal to the IC, so that it can function. And a positive supply here will bring its continuing to a standstill and will reset it.

At this position pin 3 of the IC4017 stay at positive whereas all other outputs are Negative. Pin 14 is the clock input of the IC4017 from pin 3 of 555 timer. An external clock signal to this point will make a positive signal to proceed sequentially, starting from pin 3 and ending at pin 11.

Cycle of the traffic light signal is repeated or continued as long as the clock persists at pin 14.The period of time each output stays positive will depend on the time period of the positive peaks of the clock signal. With the rising edge of every clock pulse, the positive signal will shift from one output to the other serially.

Pin 13 is the clock enable point. A positive to this pin will stop the IC4017 from proceeding and its output will freeze at that instant at the particular output. Even if the clock signal at pin 14 is ON, the output can't shift as long as pin 13 is held at positive; therefore this point should be grounded. On the contrary if pin 14 is held at positive and clock signal is applied at pin 1, every falling edge of the pulse will make the outputs to change state sequentially. [9]

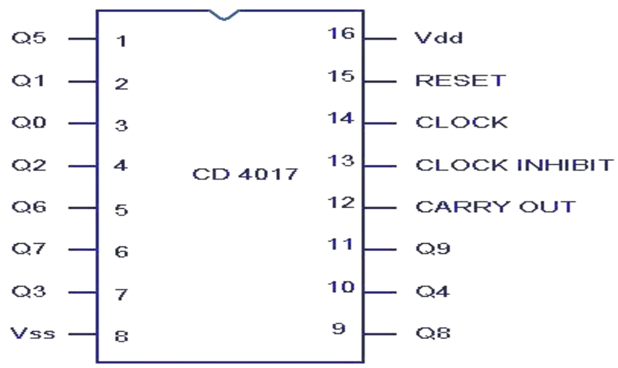

Fig. 3. 4017-pin-diagram

Mode of Operation

Cross road traffic light control system utilizes the concept of the 4017 counter. The pulses from the 555 timer in the astable multivibrator mode sets the counter, the counter being a decade counter works as a Johnson counter. i.e. each subsequent output will get high on the negative edge of the previous output pin. For example the outputs are from Q0 to Q9, as per the counter, first Q0 will get high. At the moment Q0 gets low, Q1 will start working and so on till Q9.

Now here, pin 3 is the first output, i.e. Q0. So the first glowing light will be the yellow lights of North and South signals. Then after that output Q1 gets high, then Q2, Q3, Q4 precisely pins 2, 4,7,10 . Since all of these outputs are connected to the 1N4148 diode (for obvious reasons to avoid the back-emf). The high states of these outputs are collectively joined together and the form a pretty long interval for the green lights for North and south signals as well as the red lights for East and West signals. The 100 ohm resistor provides for a sink to the extra current which can possibly damage the LEDs.

Next after illuminating the red LEDs for East and West signals, we have to show them the yellow LED namely Q5(pin no. 1), to get the engines started. The yellow LED glows for a very short duration and then again the green lights for the East and West sides glow up. Similar to above description Q6, Q7, Q8, Q9 namely pins 5, 6,9,11 are all shorted together to give this a longer interval than the yellow light. The red LEDs for North and South sides also glow up, since they are serially connected to these East and West green LEDs.

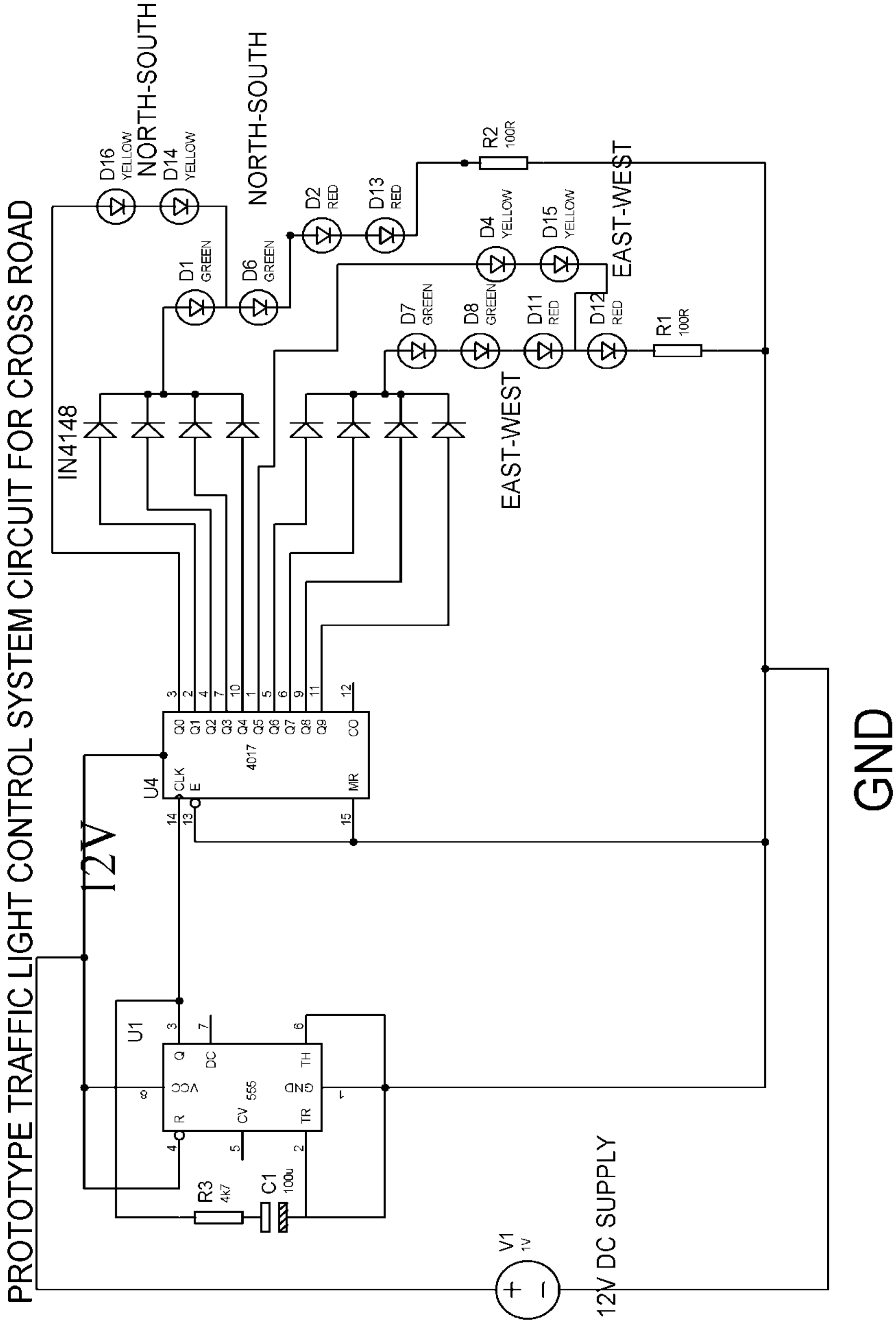

Fig. 4 Complete Circuit Diagram of a Four (4) ways or Junction prototype crossroad traffic light control system.

The 555 Timer

The 555 timer IC is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications. The 555 timer IC serves as pulse generator for the decade counter IC4017 since it works on Binary Coded Decimal which counts 10 digits(0s-9s).When the supply is applied, trigger and the threshold inputs are both below 1/3vcc and timing capacitors is uncharged. The output voltage is high and stays high for a period of time. In astable mode, the switching ON is determined by resistors R1 and R2 with capacitor C1.The frequency of operation of the astable circuit is dependent upon the values of R1, R2, and C. The frequency can be calculated with the formula f = 1/ (.693 x C x (R1 + 2 x R2)). The Frequency f is in Hz, R1 and R2 are in ohms, and C is infarads. The time duration between pulses is known as the 'period', and usually designated with 't'. The pulse is on for t1 seconds, then off for t2 seconds. The total period (t) is t1 + t2.That time interval is related to the frequency by the familiar relationship f = 1/t or t = 1/f.The time intervals for the on and off portions of the output depend upon the values of R1 and R2. The ratio of the time duration when the output pulse is high to the total period is known as the duty-cycle. The duty-cycle can be calculated with the formula: D = t1/t = (R1 + R2) / (R1 + 2R2).we calculate the values of t1 and t2 times with the formulas t1 = 0.693(R1+R2) C or t2 = 0.693 x R2 x C

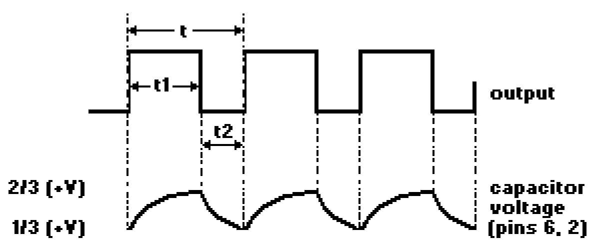

Fig. 5 The total period (t) is t1 + t2

The 555, when connected as shown in Fig.3.4, can produce duty-cycles in the range of approximately 55 to 95%. A duty-cycle of 80% means that the output pulse is on or high for 80% of the total period. The duty-cycle can be adjusted by varying the values of R1 and R2.[9,10,11]

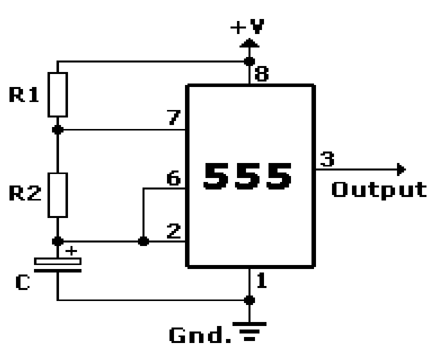

Fig. 6 shows the 555 connected as an astable multivibrator.

Rc Network

All IC timers rely upon an external capacitor to determine the off-on time intervals of the output pulses. It takes a finite period of time for a capacitor (C) to charge or discharge through a resistor (R). Those times are clearly defined and can be calculated given the values of resistance and capacitance.

The basic RC charging circuit is shown in fig.3.5. Assume that the capacitor is initially discharged. When the switch is closed, the capacitor begins to charge through the resistor. The voltage across the capacitor rises from zero up to the value of the applied DC voltage. The charge curve for the circuit is shown in fig. 6. The time that it takes for the capacitor to charge to 63.7% of the applied voltage is known as the time constant (t). That time can be calculated with the simple expression: t= R x C

Assume a resistor value of 1 MW and a capacitor value of 1uF. The time constant in that case is: t= 1,000,000 x 0.000001 = 1 second

Assume further that the applied voltage is 6 volts. That means that it will take one time constant for the voltage across the capacitor to reach 63.2% of the applied voltage. Therefore, the capacitor charges to approximately 3.8 volts in one second.[9,10]

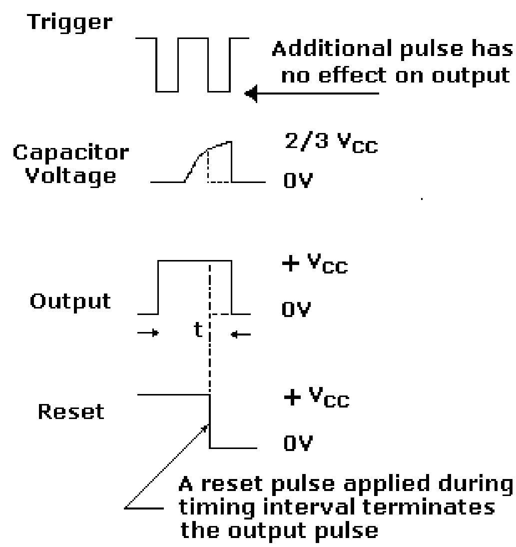

Fig. 7 RC charging circuit

Capacitor

In this design, electrolytic capacitor is used. The electrolytic capacitor is used with the resistor as charging and discharging timing circuit.

Battery

The battery is used in this design as a source of power supply to the system. The battery used is a 12V rechargeable battery. The purpose of using the battery is simply because the project was design on a model.

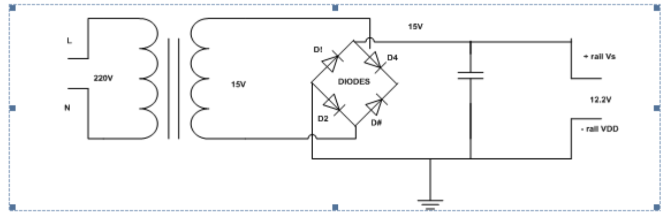

Fig. 8 Power supply Circuit

Power Supply Circuit Calculation

Supply Volt = 220V

Before output volt of Transformer, = 15VDC

After Rectification = D1-D4 = [0.7V.D]

0.7 x 4 = 2.8V

Output volt before Rectification = 15V – 2 = 12.2V

Resistor

The resistors used in the design of this project are for limiting the current flow LEDs, and to the ICs.

Toggle Switch

In this design, toggle switch is used to put On and Off the circuit manually, and to enable circuit resets.

Display

For the purpose of this design, the display panel is made up of light emitting diodes {LED}. The display is used to indicate the status of the Decade Counter and for performing the purpose for which it is meant to perform i.e. controlling the movement of traffic. Each status of the display contains four LEDs. Each lane has three status, the RED indicating ‘STOP’, the YELLOW or AMBER means ‘READY’, and the GREEN means ‘MOVE or GO’.

Calculating the LED Resistor Value

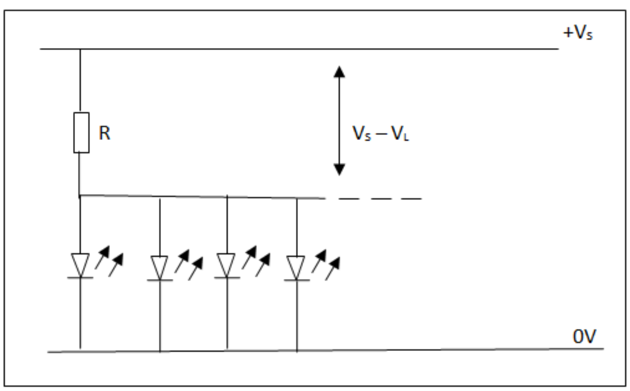

Fig. 9 Light Emitting Diode Unit

By formula R = [VS-VL]/IL

Where VS = Supply voltage

VL = LED voltage [usually 2v and 4v for blue and white LED]

IL = LED current [e.g. 20mA] this must be less than the maximum

Permitted

VS = 12v

VL = 2v

IL = 20mA

R = VS-VL = 12 – 2

IL 20 x10-3

=10

0.02 = 500Ω

Signal Diode

The function of the signal diode as used in the design is to stop emf back effect from the LEDs back to the Decade Counter IC.

Model Design

The model design is an architectural layout which represents a location or a small arena having four streets and a junction. The four roads meeting at a junction (round-about) with traffic lighting system at the road intersections.

The dimension of the layouts

Length of the model = 70cm

Breadth of the model = 50cm

Height of the traffic light stand = 7cm

Length of Street = 20cm/30cm

Length of Lane = 18cm

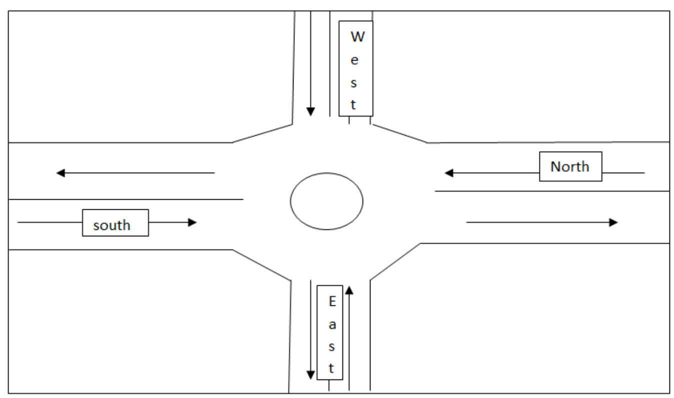

Fig. 10 Model Diagram of a Four (4) ways or Junction prototype crossroad traffic light control system.

DESIGN, ASSEMBLY AND TESTING

The design and implementation of this prototype traffic control system for cross road is demonstrated on a model, the model is an architectural design of a cross road consisting of only four roads. It also includes four streets with houses in each of these streets. The traffic light is position at the side of the junction each four roads and it is controlled by the control unit of the traffic light.

Construction

The circuit construction starts by mounting the LM555 timer, decade counter CD4017B, resistors, capacitors, and diodes on the Vero board. The Decade counter CD4017B controls the LEDs at each junction. The choice of the veroboad is simply because of its simplicity, and fault can be rectified or any additional upgrade of the circuit in nearest future.

Pulse Generator Unit

The 555 timer output is connected to input of the decade counter, in which it generate clock pulses in a stable frequency output power to drive the input of the decade counter 4017B(BCD). In the circuit it works as astable multivibrator with variable resistor to either increase or decrease the oscillation frequency.

When the capacitor voltage will becomes slightly greater than 2/3 Vcc the output of the higher comparator will be HIGH and of lower comparator will be LOW. This resets the SR Flip-flop. Thus the discharging transistor turns ON and the capacitor starts discharging through resistor Rb. Soon the capacitor voltage will be less than 2/3 Vcc and output of both comparators will be LOW. So the output of SR Flip-flop will be the previous state. So the discharging of capacitor continuous. When the capacitor voltage will becomes less than 1/3 Vcc, the output SETs since the output of lower comparator is HIGH and of higher comparator is LOW and the capacitor starts charging again. This process continuous and a rectangular wave we be obtained at the output (Pin 3 of the IC555).

Capacitor Charges through Ra and Rb (110k and 500k V.R)

Thigh = 0.693(110x103 + 500x103) 10x10-6 =4.2273Hz

Capacitor Discharges through Rb

Tlow = 0.693RbC

0.693x500x103x10x10-6=3.465Hz

Duty Cycle = Thigh/ (Thigh + Tlow)

4.2273/ (4.2273+3.465) =0.5496Hz

Where Thigh and Tlow are the period of High and LOW of the output of 555.

Decade Counter (Binary Coded Unit)

When the Nth decoded output is reached (Nth clock pulse) the S-R flip-flop neither (constructed from two NOR gates of the HCF4001B) generates a reset pulse which clears the HCF4017B to its zero count. At this time, if the Nth decoded output is greater than or equal to 6, the COUT line goes high to clock the next HCF4017B counter section. The "0" decoded output also goes high at this time. Coincidence of the clock low and decoded "0" output high resets the S-R flip-flop to enable the HCF4017B. If the Nth decoded output is less than 6, the COUT line will not go high and, therefore, cannot be used. In this case "0" decoded output may be used to perform the clocking function for the next counter.

Display Unit

The LEDs are arranged in matrix array and grouped into four by LED of the same colour and later grouped into three LEDs of the same direction.

The LEDs are powered ON and OFF by the Decade counter via the pin 1 to pin 7 and pins 8, 9, 10 are all the outputs and the overall control of the LED is done by the Decade counter which is pulsed by the 555 timer oscillate from time to time.

This then reduces then power consumption of the system drastically which make it suitable to be powered by battery.

Testing

The physical realization of the project is very vital, that is where the fantasy of the whole idea meets reality. I can see the design work not just on paper but also as finished system. After carrying out the design and construction, the project was tested to ensure it works. The process of testing and measurement involved the use of the following equipments.

Digital Multimeter: The digital multimeter was basically used to measure voltage, resistance, continuity and current. The process for the implementation of the design on the board requires the measurement of parameters like voltage, continuity and resistance values of the component and in some case frequency measurement.

Bench power supply: This was used to supply voltage to the various stages of the circuit during the breadboard test before the power supply in the circuit was built. Also during the soldering of the project, power was fully used to test the various stages before the d.c power supply was used for the device.

RESULT

The design and construction of a Prototype traffic light control system for crossroad was developed with the following results.

1. Automatic on and off operation of traffic light.

2. Increment assignment to the busiest lane.

The performance evaluation of the traffic system was carried out. The model testing was performed at different occasions of light changing and the result below was achieved.

Initial time of operation of all the lanes = 2 seconds

Amber duration = 3 seconds.

Red duration = 8 seconds

Green duration = 4 seconds

1 = On

0 = Off

Table 1 NORTH-SOUTH Lane Evaluation for Red Light

	NORTH	EAST	SOUTH	WEST
RED	1	0	1	0
AMBER/YELLOW	1	1	1	1
GREEN	0	1	0	1

Table 2 NORTH-SOUTH Lane Evaluation for Green Light

	NORTH	EAST	SOUTH	WEST
RED	0	1	0	0
AMBER/YELLLOW	0	1	0	1
GREEN	1	0	1	0

Table 3 EAST-WEST Lane Evaluation for Red Light

	NORTH	EAST	SOUTH	WEST
RED	0	1	0	1
AMBER/YELLOW	1	1	1	1
GREEN	1	0	1	0

Table 4 EAST-WEST Lane Evaluation for Green Light

	NORTH	EAST	SOUTH	WEST
RED	1	0	1	0
AMBER/YELLOW	1	0	1	0
GREEN	0	1	0	1

This project has greatly broaden our understanding generally on the professionalism of electronic engineering especially on the principle of operation of cross road traffic lighting control systems and has got us acquainted with some component typical and related faults and problems often found with electronic circuit and system, and also how these faults can be rectified.

SUMMARY

This project is intended for the design and implementation of prototype cross road traffic light control system.

The design was achieved by taking up the challenges of making findings from library, internet and also interview from resourced persons about the essential facts of the design.

The design proceeds to getting all necessary components to initialize and maintain the proper functions of the designed circuit. The control circuit was properly designed and faults were corrected before mounting the circuit into the model. It is quite challenging mounting the components on the Vero board because of the fragility of the components and the total concentration and perfection required to achieve an accurate output or result. Proper functioning of the circuit and an error free connection was ensured.

The circuit was finally put to test and automatic control of the traffic light was achieved by the decade counter.

CONCLUSION

Automatic traffic lighting system is useful equipment for controlling traffic flow at junctions.

This method has for long outweighed1 the older system in many ways it is more efficient and effective as well, as it can enhance the transportation system of the country saving many hours usually lost in traffic problems. Accidents may also be prevented and lives can be saved.

RECOMMENDATION

Automatic traffic light control system is useful equipment for controlling traffic at junctions.

More attention should be given to this method of automatic traffic light system by the government, individuals and even drivers as it posed to reducing or preventing road accidents thereby reducing or preventing loss of live associated with it.

The government should endeavor to encourage the installation of this system of traffic at necessary junctions in order to reduce the number of accounts associated with road.

Drivers and pedestrians should also learn to abide by the rules associated with the system so as to ease traffic congestion and avoid unnecessary stress on the road and fear of crossing intersections by the pedestrians.

Higher institution of learning most especially engineering fields should devote time and resources to the project as it would be of great benefit to students and researchers.

It is our belief that a greater design can be achieved if standard equipment, materials and components are used. We could not fail to commend that this design still stands much room for improvement.

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