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Design and Implementation of a 4-Way Traffic Controland Detection System

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Abstract*. Traffic control and management is one of the primary problems faced byroad users in manypopulated cities. People get tired and frustrated at crossed-junctions without traffic control systems waiting for their counterpart road users to pass before they could move further which often times makes people furious and decide to cross the roads and get subjected to accidents. Even at cross-junctions where traffic control systems are installed, some notorious motoristsdrive through cross-junctions without obeying traffic rules and end up causing accidents, and yet go freely without been arrested especially at late hours when road wardens are unavailable. This paper presents a detailed design and construction of a 4-way traffic controller with violation detection system that is capable of detecting traffic violators from the traffic junction and automatically sends signal to the receiver's station for necessary action. The designed system has two controllers which control devices at the station and the traffic junction. At any point a violator is detected, the servo motor turns the internet protocol (IP) camera in that directionandtakes a snap shot of the plate number of the violating vehicle for proper action.In a situation where there are no violators, the traffic controller opens each lane for an allocated time and thereafter moves to the next lane and the process continues.*
Keywords: *Traffic controller, Violation detection, Traffic congestion, IP camera, Ultrasonic sensor*

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I. Introduction/Background

In recent years, more people have migrated from rural to urban centres for greener pastures. Increase in population, rural-urban migration, social activities and industrialization around the globe has led to usage of more vehicles which has led to emergency crises in traffic control and management. A comparable and matching education program is needed through driver-licensing authorities to ensure that road users understand traffic rules and the necessary actions required when a particular situation presents itself. Every traffic control system is governed by standards of design and usage; for example, stop signs usually have a red background with octagonal shape. Design standards allow motorists to quickly and consistently perceive road signswhile on the road. Standard use of colors and shapes aids identificationof road signs and the appropriate actions required. Traffic congestion can lead to drivers' frustration which often results in violation of traffic rules and regulations, such as breaking the speed limits and stop signs infractions [1].

Increase in traffic congestion is one of the major reasons for traffic violations. Road users tend to violate traffic rules when there is traffic congestion. As road demand approaches its capacity, extreme traffic congestion becomes eminent. When moving vehicles are fully stopped for a while, it results to traffic congestions and further makes drivers angered [2]. In an attempt to avoid the physical and emotional stress of traffic congestion, impatient road users tend to boycotting the traffic congestion to an extent of violating the traffic laws, a situation that has led to so many accidents, loss of valuable properties and lives.

II. Survey of Related Empirical Studies

Numerous techniques have been proposed by many researchers for the design of traffic control systems. [3] designed a completely unique real-time system which evades traffic using image processing. In each stage of traffic, a webcam is used to collect pictures of the roads prone to traffic congestion. Dynamic timingswere assigned in accordance with the count in conjunction with traffic colour signals. [4] designed a density-based traffic light system with a PIC microcontrollerusing IR sensors. For each road, three IR sensors were installed,the space between these sensors depends on the traffic character of a particular junction, asthese sensors were designed to sense the buildup of vehicles on a particular road. The controller recognizes the traffic congestion and finds out the time delay of signals dynamically. This system uses an IR sensor-interfacing with PIC microcontroller. Three IR transmitters and IR receiverswere also positioned for each road. When a vehicle crosses between certain IR sensors, the photodiode is activated and therefore, the object is detected and the counter gets a clock pulse. The data collected about the vehicle density for each junction and road are analyzedanddisplayed accordingly. Traffic density is measured as low, medium and high.

[5]deployed anacoustic technique that utilizes an array of sound detecting equipment to detect sound waves generated by trucks passing on the highway. The detected signals are sent for digitization and processed by an on-site computer employing an algorithm which utilizes the concept of correlation in which algorithm factors influencing the density of traffic are estimated. As compared with existing sensors of the clustering traffic, the space between these sensors depends on the traffic character of a particular junction as these sensors sensed the buildup of vehicles on a particular road. Thecontroller recognizes the traffic congestion and finds out the time delay of signals dynamically. These frameworks give a continuous information discovery and also serve as warning instrument to identify violations, and further advise the police and the vehicle owner of the submitted infringement so as to take appropriate actions.

[6] proposed an algorithm that recognizes the plate number of a vehicle with accuracy but faced with difficulty in localizing the plates.Number plate acknowledgement is a successful route for programmed vehicle distinguishing proof. Vehicle Number Plate Detection (VNPD is a robust transportation and mass surveillance framework that identifies the nature of vehicle and perceives their permit numbers.Automatic vehicle number plate recognition with possible projection profileis economical and quick, but does not incorporate possible chances of number plate detection. A system proposal for dynamic traffic control based on number plate detection with messaging systemis essential [7].

[8] developed a density-based dynamic traffic light system in which the signal light varies in timing. The architecture consists of a Passive Infrared Sensor (PIR) which is interfaced with an Arduino microcontroller through sensing of traffic signal. Time is extended for the traffic dense lane, which makes it an efficient traffic-controlled system. This system gives the illusion of delay adjustment of traffic signals supported by the number of vehicles passed through an allocated section of the road.

III. Materials and Methods

Thisresearch work is based on the design and implementation of a 4-way traffic controller with detection system made from the following materials: Aduino Mega 2560, lightemitting diodes (LEDs), internet protocol cameras, Transmitter and receiver modules, transistors, resistors, diodes, capacitors, step-down transformer, voltage regulator, NPN Darlington transistor (ULN2003), servo motors, ultrasonic sensors, PCB board, flexible cables and soft wooden board.

3.1 The Power Supply Circuit

The power supply is an important section of the entire circuit. The power supplied to the circuit is delivered from the mains after conversion from AC to DC for use by microcontrollers and other components that requires 5 VDC supply. The power supply section is made up of rectification circuit as shown in Figure 1.

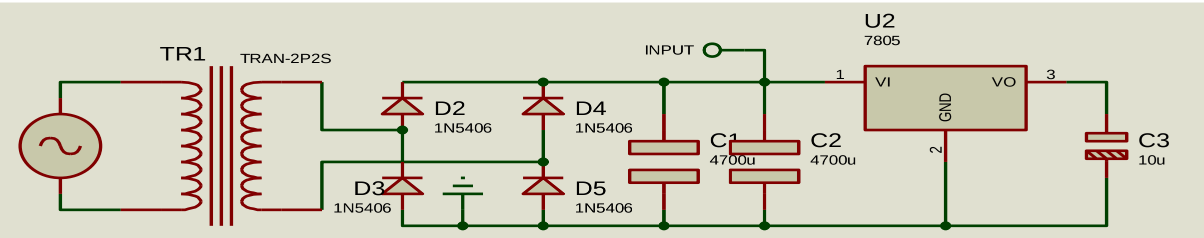


Figure 1: Power circuit

The input AC voltage from the mains is stepped down from 220-240 V to 12 V. This is further rectified using a four 1N5406 diode arranged in a bridge circuit producing both negative and positive cycles as outputs known as full wave rectification.The four diodes are arranged such that only two diodes conduct current during each half cycle. During the positive half cycle of the supply, two diodes (D_2 and D_5) conduct in series while the other two diodes (D_3 and D_4) are reversed biased and the current flow through the load. Due to the varying nature of the input voltage with time, the rectified voltage contains some ripples that are not purely DC, hence the need for all AC components of the output to be removed or filtered out in order to get pure DC output voltage. Capacitors $C_1$and C_2 were used to filter available ripples that may be present. A voltage regulator U27805 stepped down the 12V DC to 5 V and further filtered byC_3 before supplying the system's main circuit.

Filter capacitor selection:

The choice of the filter capacitor is based on equation 1.0

$$C = \frac{I_{DC}}{4\sqrt{3}\gamma f V} \qquad 1.0$$

whereγ is the percentage allowable ripple, I_{DC} is the direct current, $V_{IN} = 12$ V is voltage and f is the supplied operatingfrequency.
Peak Inverse Voltage (PIV) = $\sqrt{2} \times 12\ V = 17\ V$
Given that: γ = 3%, f = 50 Hz, V_{DC}=12 V and I_{DC} = 2000 mA = 2 A

$$C = \frac{2}{4\sqrt{3} \times 0.03 \times 50 \times 12} = \frac{2}{124.7076}$$

C = 16.0375×10^{-3} F = 16037μF, two of the 4700 μF capacitors were connectedin parallel for better results.

3.2 The Power Supply for Servo Motor

Servo motors are high toque, high current demanding electrical machines. In this design, the motors are required to carry a load at high speed in order to meet up with specifications. Hence, we have two different 6V voltage regulators (U7806) because each can deliver comfortably without excessive heating as the motors requires 0.7A to run at the design specifications.The capacitors were selected according to the time constant

$$RC = t$$

where t is the allowable time, R and C are the values of the resistor and capacitor respectively that will guarantee the time.The intended capacitor brand to be used for $t = 2secs$ and the resistance required for the input is 0.02MΩand the output resistanceof0.2MΩ is evaluated as

$$C_4 = C_6 = \frac{t}{R} = \frac{2}{0.02 \text{ x } 10^6} = 100\mu F$$

$$C_5 = C_7 = \frac{t}{R} = \frac{2}{0.2 \text{ x } \text{ x } 10^6} = 10\mu F$$

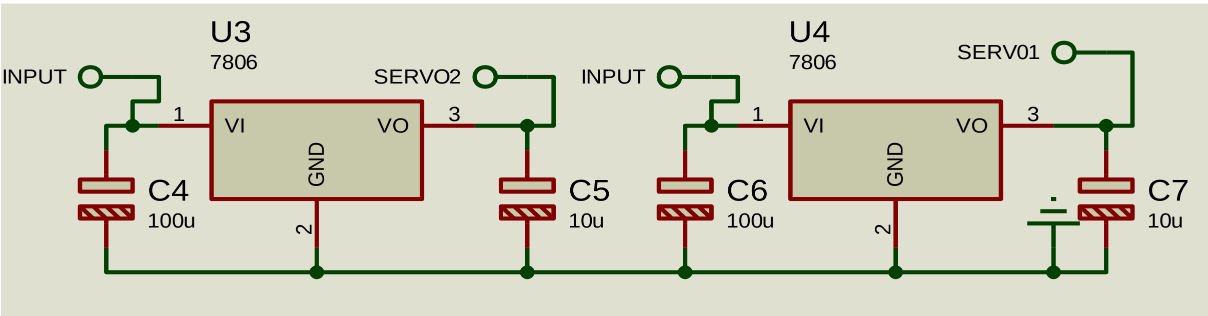


Figure 2: 2No 6 V Voltage Regulation for Servo Motor

3.3 The Range Sensor Circuit

The range sensor or ultrasonic sensor is used to detect vehicles violating traffic rules. The sensor sends signals of known frequency to an obstacle and waits for its echo. This echo determinesthe distance between an obstacle and the sensor. Hence, it is used in this research work to determine velocity of vehicles and their distances. The computed distances are used to find the slope of a straight line. A capacitor is connected between its power rail and ground for noise filtration.

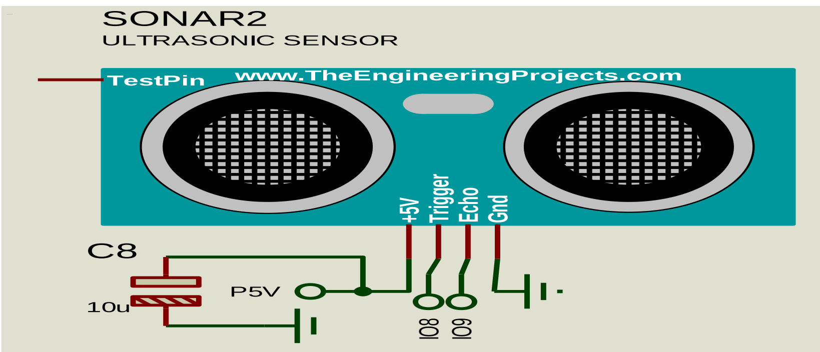


Figure 3: Range sensor

3.4 Configuration of Servo Motor Circuit

The servo motors are configured as shown in Figure 4. The capacitors are connected for filtrations, while control signals are supplied from the microcontroller through the pins labeled MCU_1 and MCU_2

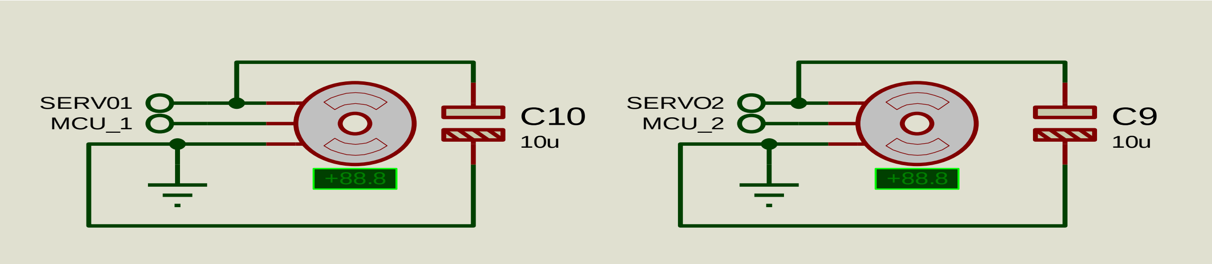


Figure 4: Configured Servo Motors

3.5 Configuration of Traffic Light

The traffic lights (LED) are biased using KVL loop laws to determine the values of their limiting resistors.
From the data sheet for Green LED, the voltage drop across the diode is 2.2V and the full drive current is chosen to be 20 mA.
Using Figure 5, takingKirchhoff's voltage law (KVL) loop equation from the 5V to ground gives,

$$20R_1 + 2.2 = 5 \quad 2.0$$

$$R_1 = \frac{2.80}{20} = 0.14k\Omega$$

Therefore, $R_1 = 140\Omega$is chosen.

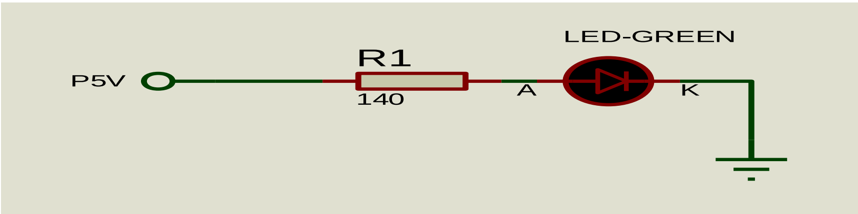


Figure 5: Biased Traffic light (Green LED)

From the data sheet for Red LED, the voltage drop across the diode is 1.8V and the full drive current is chosen to be 20 mA.
Using Figure 6, taking KVL loop equation from the 5V to ground, we have:

$$20R_2 + 1.8 = 5 \quad 3.0$$

$$R_2 = \frac{3.20}{20} = 0.16\ k\Omega$$

Therefore, $R_2 = 160\ \Omega$is chosen.

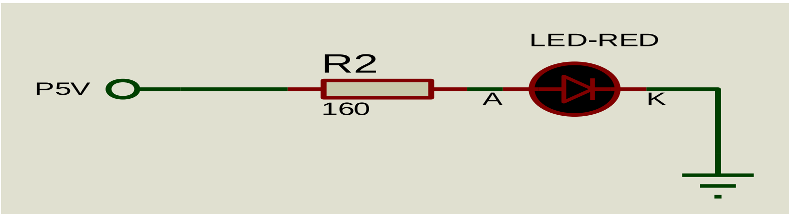


Figure 6: Biased Traffic light (RED LED)

From the data sheet for Yellow or Amber LED, the voltage drop across the diode is 2.0 V and the full drive current is chosen to be 20 mA.
Using Figure 7, taking KVL loop equation from the 5V to ground, we have:

$$20R_3 + 2.0 = 5 \quad 4.0$$

$$R_3 = \frac{3.0}{20} = 0.15k\Omega$$

Therefore, $R_3 = 150\ \Omega$ is chosen.

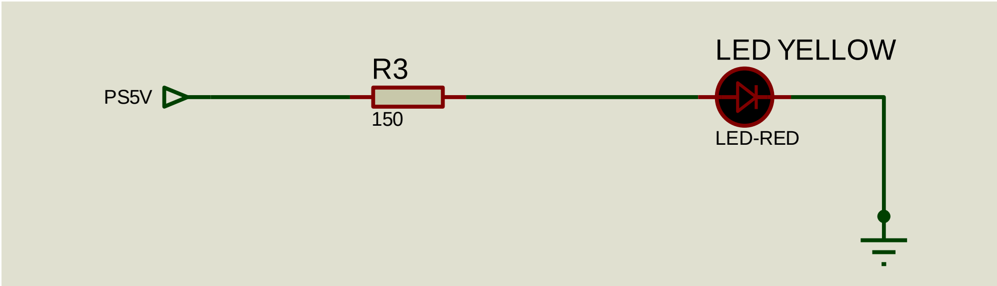


Figure 7: Biased Traffic light (Yellow LED)

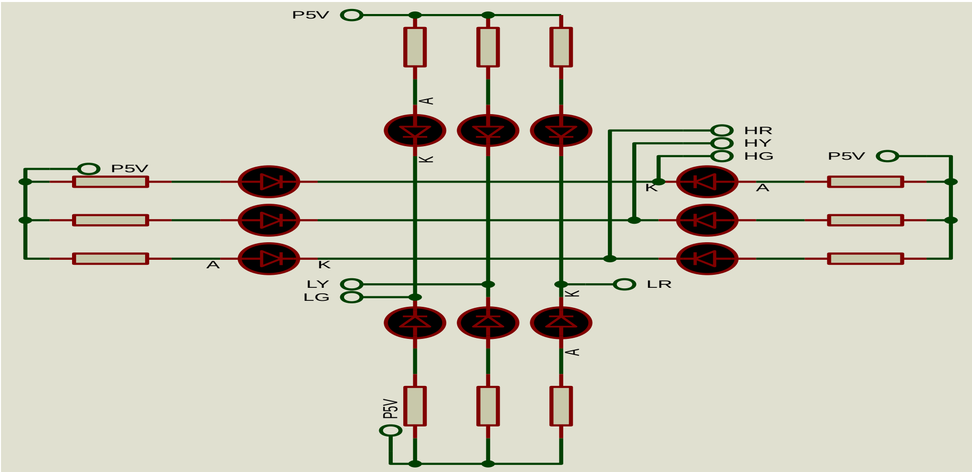


Figure 8: Complete 4-Way Traffic Light

3.6 The Buzzer Circuit

Buzzer data: 5 V, 25 mA.

Transistor Saturation Mode data: $V_{BE\,(SAT)} = 0.80\,V, V_{CE\,(SAT)} = 0.2\,V\ and$

$h_{FE\,(SAT)} = 100.$

Using Figure 9, taking(KVL) loop of C – E loop and making I_C the subject of the relation:

$$I_c = \frac{5 - V_{CE}}{\text{R}} \quad 5.0$$

where R is buzzer resistance

$$R = \frac{buzzer\ voltage}{max.\,buzzer\ current}$$

$$R = \frac{\text{5V}}{\text{25mA}} = 200\ \Omega$$

Therefore,

$$I_c = \frac{5 - 0.2}{200} = 24\ mA$$

Similarly, taking KVL of B – E loop yields:

$$I_B = \frac{5 - V_{BE}}{R_4}$$

where R_4 *is the base resistance*

$$I_B = \frac{5 - V_{BE}}{R_4} = \frac{5 - 0.8}{R_4} = \frac{4.2}{R_4}$$

Condition for saturation

$$I_C < h_{FE} I_B \quad 6.0$$

Substituting the values of I_B and h_{FE} in equation 6.0 gives

$24mA < 100\ x \frac{4.2}{R_4}$

$R_4 < 1\,7.5k\Omega.$

Note: The value for the base resistor calculated is too high and will not allow the transistor to draw enough current from the microcontroller for optimal performance. Therefore,1 $k\Omega$ for $R_4$is appropriateto ensure minimal current flow through the transistor.

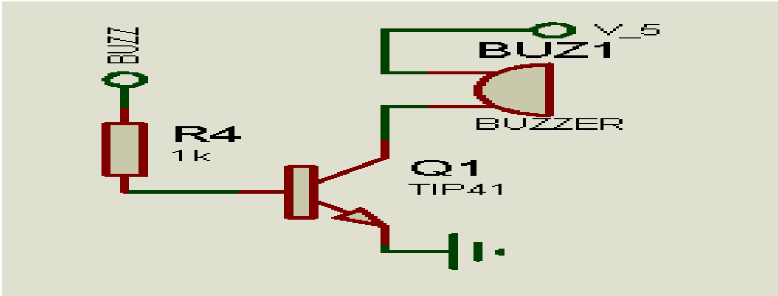


Figure 9: Analysis of the buzzer circuit

3.7 The Arduino Mega 2560 Microcontroller

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; it can be connected to a computer with a USB cable or powered with an AC-DC adapter or battery to get started[8].

3.8 The Block Diagram

This research work is presented in sections of blocks which shows direction of data flow. The microcontroller unit sends and receives information from other subsystems linked to it. The ULN2003 is the LED driving circuit which grounds the LEDS as instructed by the microcontroller unit while the ultrasonic sensordetects vehicles violating traffic signs. The servo driver drives the servo motor and turns the IP camera to the direction where violation is taking place for a snap shot while the RF transmitter sends signal upon traffic violation to the receiver.The RF receiver sends signalreceived from the transmitter back toits microcontroller which in turn triggers the buzzer to produce an alarm sound while the LCD screen produces the picture andother detailsofthe violating incident at the traffic junction.

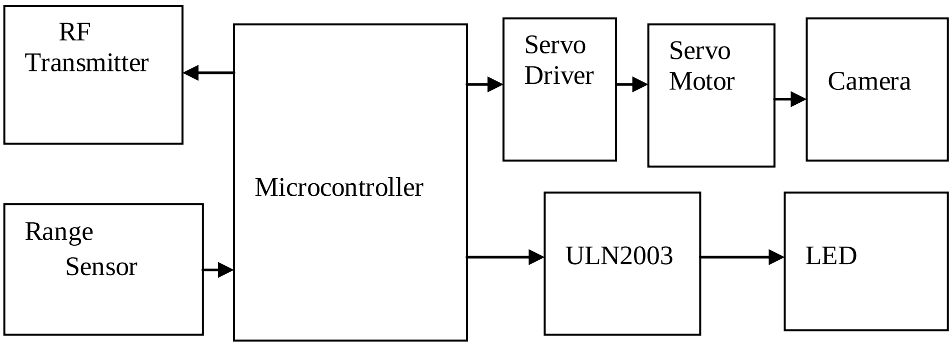


Figure10: Block diagram for the transmitter/violation system

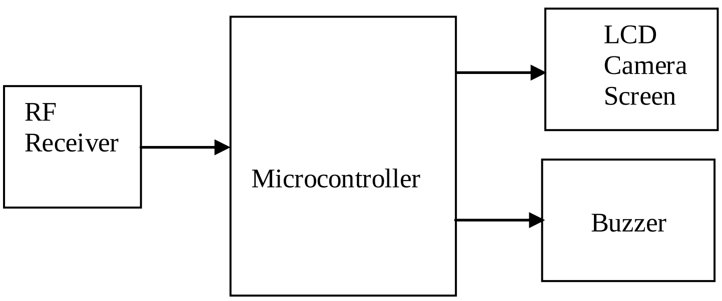


Figure 11: Block diagram for the receiver's system**.**

3.9 Flow Chart and Decision Process

In order to achieve an orderly flow process without violation, the possible flow of traffic signal is discussed below; each lane has sets of direction, the overlaps and the divergences.

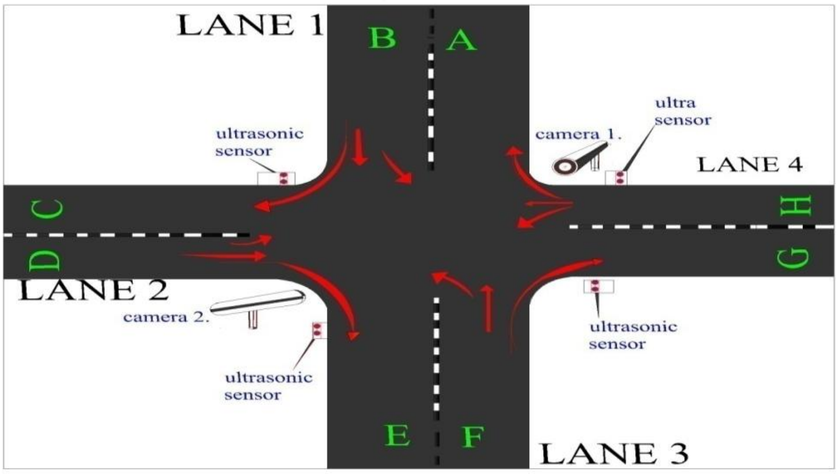


Figure 12: Cross Junction Flow of Traffic (drawn using AutoCAD)

The flow of traffic is treated in roads; we either have a road to move to and the road not to move to. The road to move to and the road not to move to for each lane are listed in Table 2 – 5.

Table 2: LANE 1

S/N	CONCURRENT ROAD	CONFLICTING ROAD
1	B-E	D-G
2	B-G	F-A
3	D-E	H-C
4	H-A	F-C
5	F-G	H-E
6	B-C	D-A

Table 3: LANE 2

S/N	CONCURRENT ROAD	CONFLICTING ROAD
1	D-G	B-E
2	D-A	F-A
3	D-E	H-C
4	H-A	F-C
5	F-G	H-E
6	B-C	B-G

Table 4: LANE 3

S/N	CONCURRENT ROAD	CONFLICTING ROAD
1	F-A	D-G
2	F-C	B-E
3	F-G	H-C
4	H-A	D-A
5	D-E	H-E
6	B-C	B-G

Table 5: LANE 4

S/N	CONCURRENT ROAD	CONFLICTING ROAD
1	H-C	B-E
2	H-E	D-G
3	H-A	F-A
4	B-C	F-C
5	D-E	B-G
6	F-G	D-A

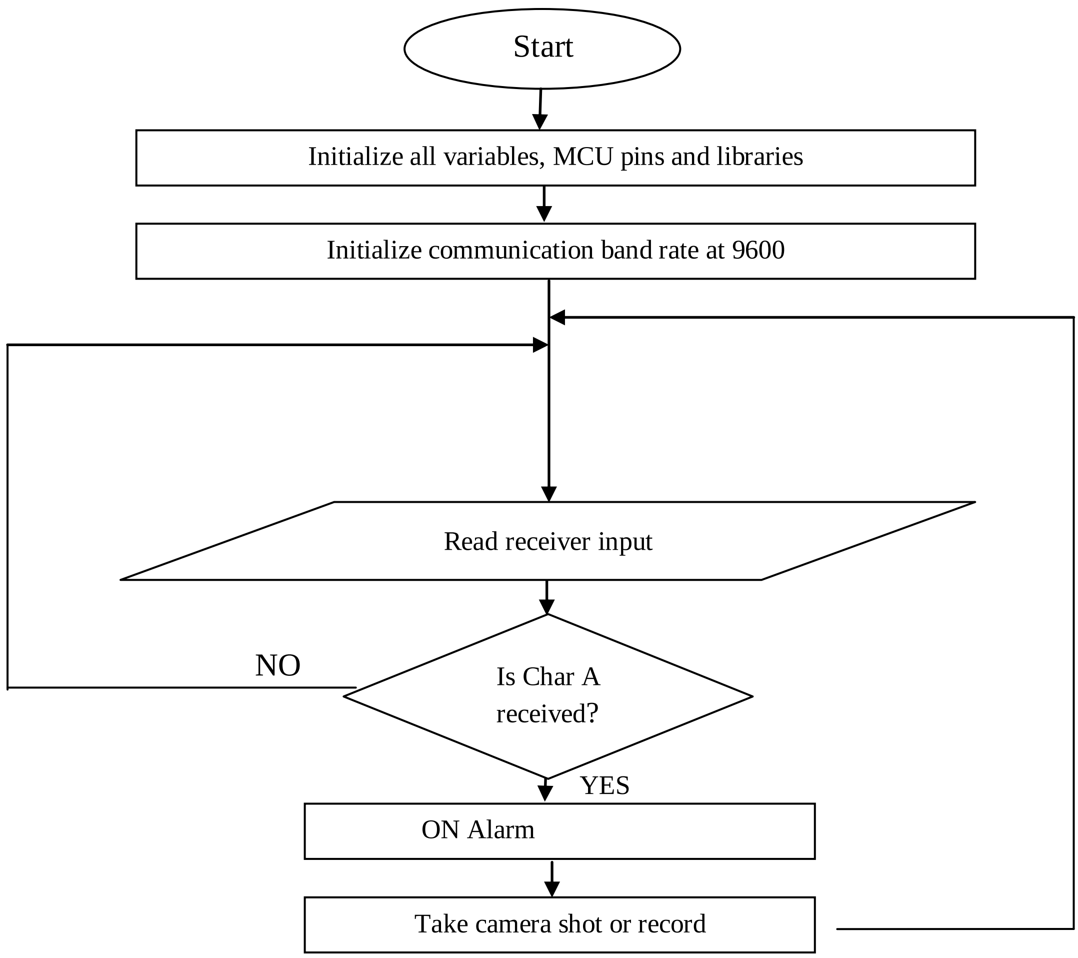
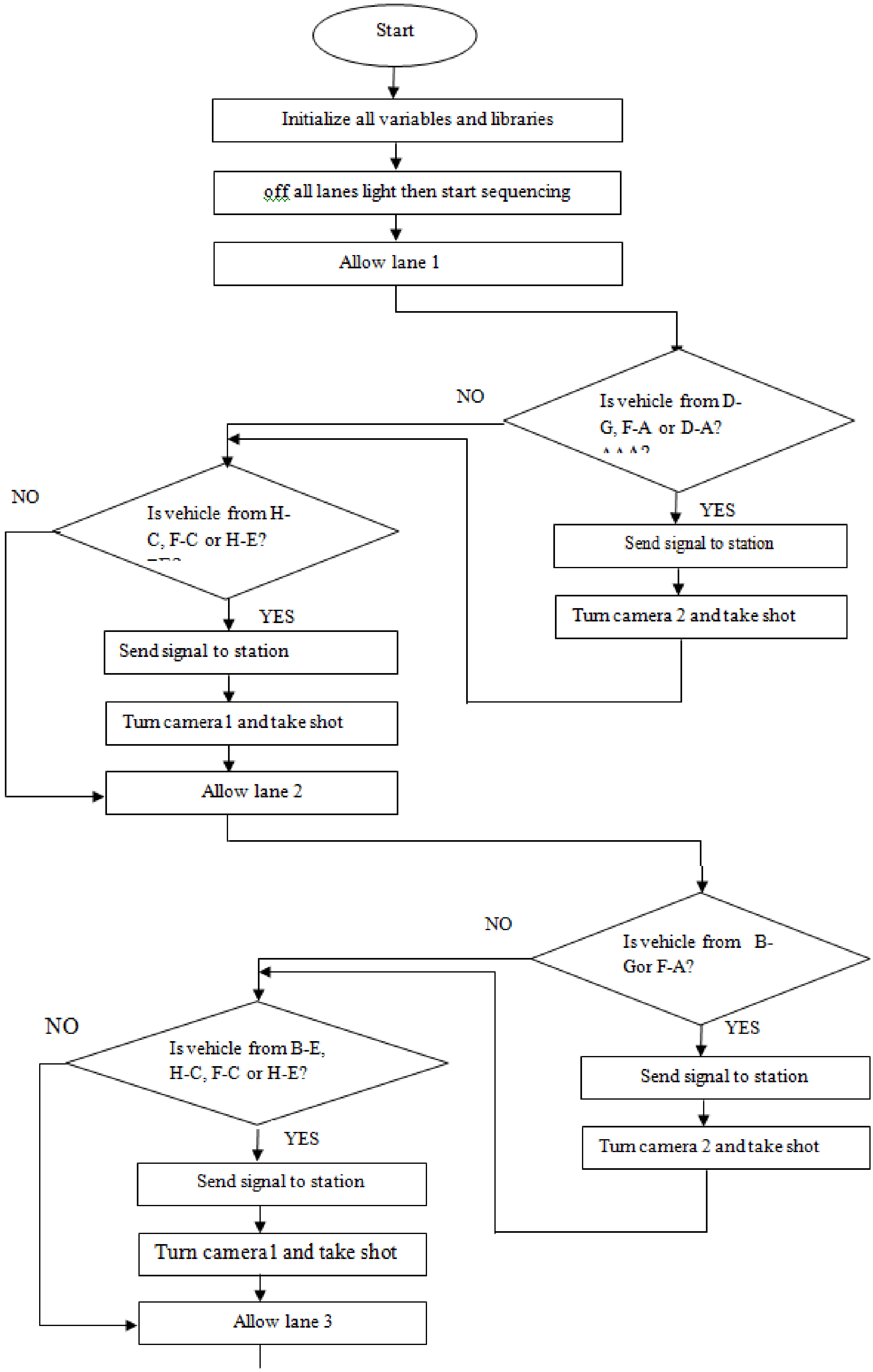


Figure 13: Flow chart for the receiver's system


Start
Initialize all variables and libraries
off all lanes light then start sequencing
Allow lane 1
Is vehicle from D-G, F-A or D-A?
NO
YES
Send signal to station
Turn camera 2 and take shot
Is vehicle from H-C, F-C or H-E?
NO
YES
Send signal to station
Turn camera 1 and take shot
Allow lane 2
Is vehicle from B-Gor F-A?
NO
YES
Send signal to station
Turn camera 2 and take shot
Is vehicle from B-E, H-C, F-C or H-E?
NO
YES
Send signal to station
Turn camera 1 and take shot
Allow lane 3

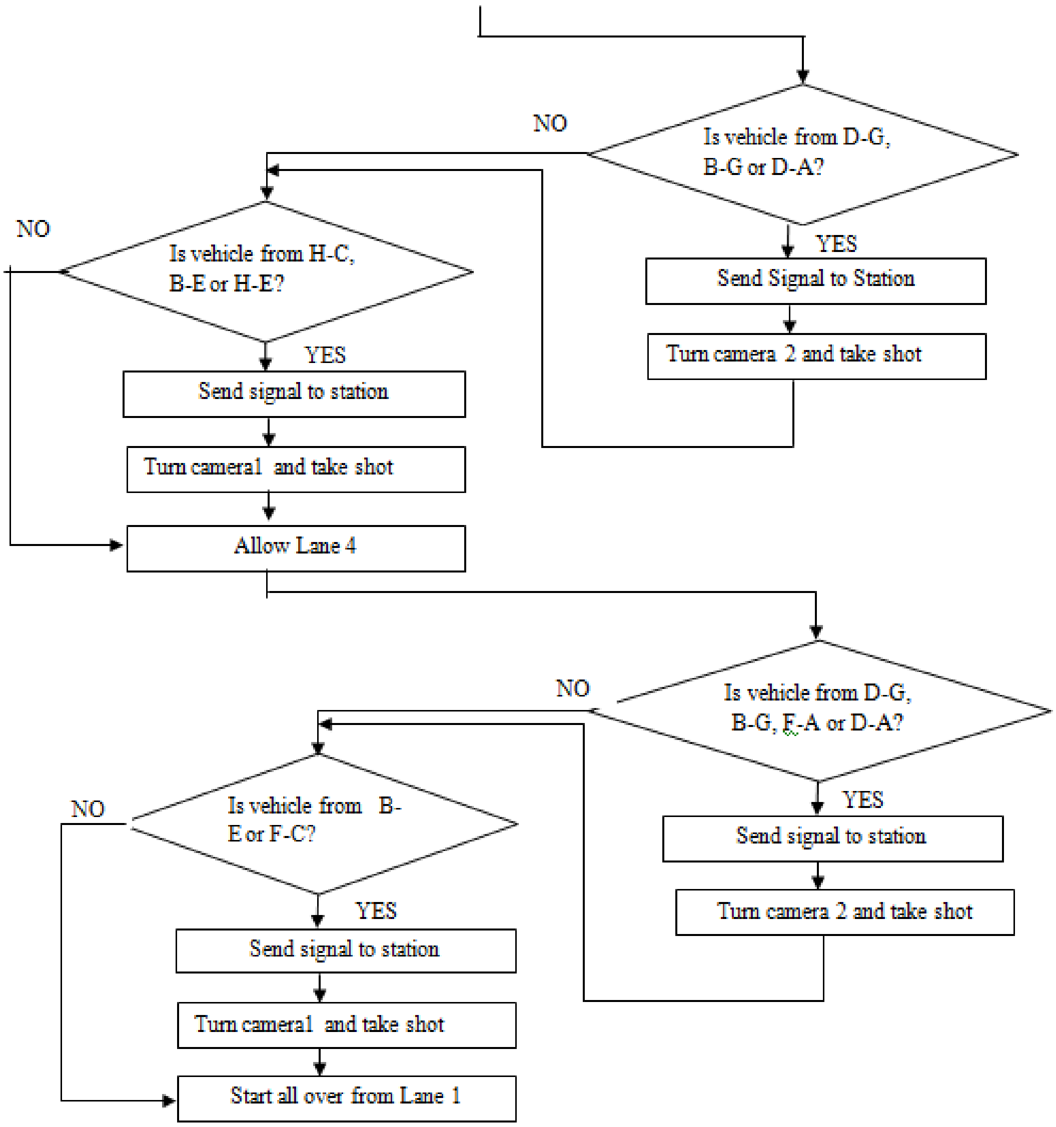


Figure 14: Flow chart for the transmitter/violation system.

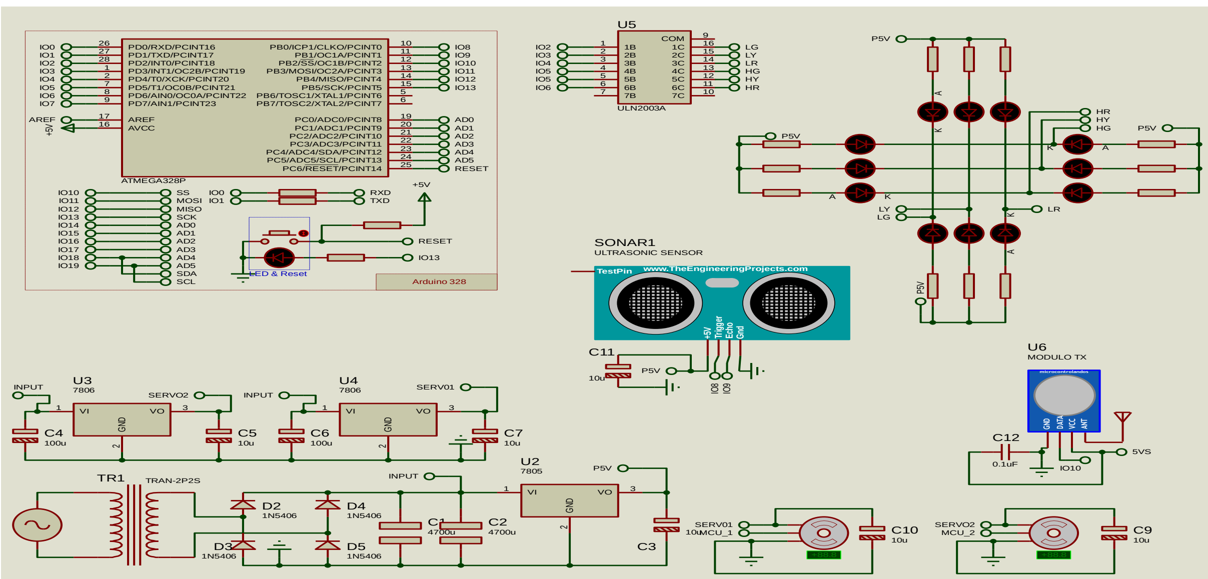


Figure 15: Complete circuit diagram for traffic controller with violation system

3.10 Working Principle of the System

This system is designed to work on the principle of object detection where the ultrasonic sensor detects vehicle within its range of coverage and sends the information to the microcontroller. The microcontroller takes action by sending the corresponding command to the servo motor through the servo drive and as a result the servo motor turns the camera coupled to it at the appropriate angle and takes a shot of the plate number of the violating vehicle. The shot taken from the transmitting junction is sent to the control (receiver's) station through the RF module where it alerts the operative by sounding an alarm through the buzzer and also display the lane, date and time of violation on the liquid crystal display (LCD).

IV. Results and Discussion

4.1 Project Construction

This projectwasimplementedin stages; starting from the design, analysisand the use of proteus software environment for simulations and drawings of circuit schematics after which constructions were made on PCB (Printed Circuit Board). The constructions were done in stages from the power circuit,traffic light to the ultrasonic sensor circuit, the RF transmitter and receiver module. Amodular approachwas adoptedin the design and implementation of the project.

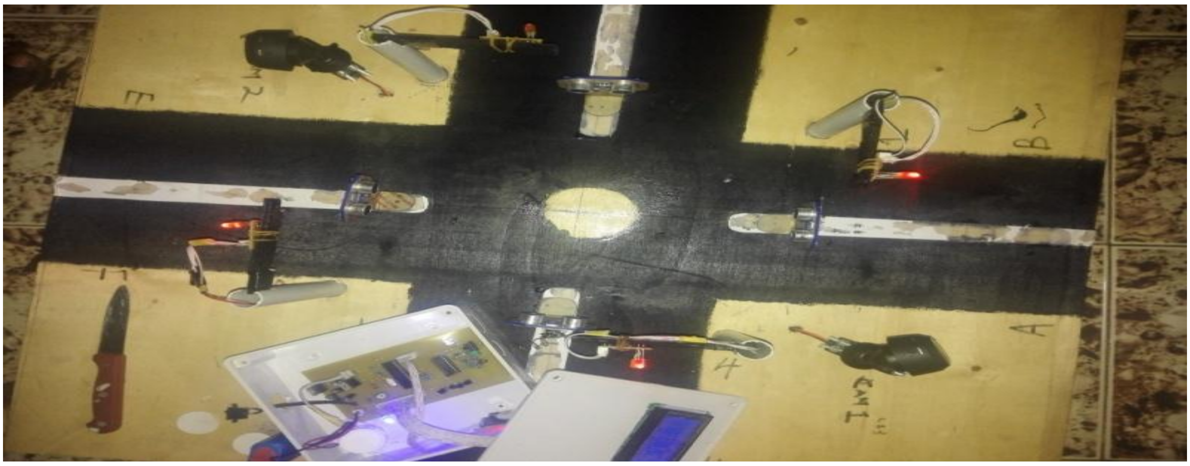


Figure 14: Testing of the designed system

4.2 Testing and Discussion

Different sections of the circuit were tested individually. The power supply circuit was tested and the temperatures of the voltage regulators were examined to be satisfactory, hence the use ofheat sink was needless. The RF transmitter and receiver circuit were tested and confirmed satisfactory. Also, the ultrasonic sensors were individually tested and confirmed normal. The servo motors were tested and confirmed to be workingoptimal. The stability of thesystem was ascertained before it was powered after careful inspection on the PCB in order to ensure appropriate connections and continuity. Polarity test was also conducted on the various circuit components in order to ensure appropriate termination. Figure 14 shows the testing process of the entire system.

4.3 Final Construction and Packaging

The final packaging of the project was done on wooden board, black paint was used to mark lanes. Traffic light poles were made from plastic conduit pipes andmounted on the wooden board at right angle to form an elbow. Ultrasonic sensors were slotted using its stand and placed on the wooden boardwith the help of glue bond. Rubber bands were used to hold the various traffic lights (LEDs) on the poles. The final packaged system is shown in Figure 14:

V. Conclusion

A4-way traffic controller with violation detection system has been designed and built as presented in this paper. The system is developed to control traffic efficiently in order to avoid collision of vehicles and other forms of accidents among road users. The Arduino Mega 2560 microcontroller is used to coordinates and give instructions to other interconnected subsystems for effective responses. The right of way is shown to users with the aid of traffic light consisting of Red LED, Yellow LED and Green LED respectively. The ultrasonic sensor helps to detect violations while the servo motor turns the IP camera towardsthe point of violation to capture the vehicle violating traffic. The captured information of the violation incidence from the transmitting station (traffic junction)is sent to thereceiver's station with the aid of internetsupport network.The lane, vehicle identity, date and the time the violation took place is displayed on the LCD screen at the receiver's station.The designed system achieved the aim and objective of the research in terms of systematic traffic control as well as detection of traffic violation cases.

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