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Full Length Research Paper

Design and implementation of a model (ADS-3G) of a traffic light using automated solar power supply

D. A. Shalangwa

Department of Physics Adamawa State University, Mubi. Nigeria. E-mail: deshalangs3g@yahoo.com.

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In this work, a model of an automated traffic light controller (ADS - 3G) had been designed, simulated, tested and implemented, using experimental techniques in electronic engineering, to manage the traffics at the busy four way junctions along Sahuda road in Mubi North Adamawa State, Nigeria. The designed was achieved with the help of 12V automated solar energy power supply, time base (555 timer), decade counter, D-flip-flop, timing sequence selector for red, green, amber and yellow light and relay circuit for switching the appropriate light. The average volume of vehicular traffics observed for the period of one week (4/4/07 - 11/4/07) for Masalachi, Stadium, Sahuda and Sarki roads are 2368, 1996, 1982 and 138, respectively which prompted the development of the model (ADS - 3G) to allowed 17.50, 14.00, 10.50 and 7.00 s accordingly. This model is capable of eliminating the inefficiency and likely error associated with human traffic controller by minimizing accident and unnecessary traffic jams at the junction.

Key words: Solar energy, traffic jam, traffic flow, traffic light controller and human traffic.

INTRODUCTION

Mubi is the second largest town in Adamawa state of Nigeria, it lies between latitude 9° 30' and 11° North of the equator and longitude 13° and 13° 34' East of Greenwich meridians, Mubi has a land area of 4728.77 km^2 and a population of 759,045 (Adebayo, 2004). Mubi has many road junctions; but cases of accidents are more often recorded at Sahuda road junction especially from 2003 to date (Road Safety, 2005). Mubi has been experiencing increasing volume of vehicles/motorcycles traffic which leads to increased in the risk of accident occasioned by motorists contending over right of lay in the roads. There are also problems of traffic jam on the road. The situation becomes worse on daily basis, at the road junction and much more critical at the Sahuda road junction. Accident generally leads to loss of life, destruction of vehicle and bring unnecessary delay to vehicles and also the solar energy power supply is been introduced in this design because of the inconsistency of electrical power supply by the Power Holding Company of Nigeria (PHCN), sometimes the power supply is less than eight hours in a day which consequently renders the traffic light controller useless. It also has some advantages over electrical power such as it is free in nature, easy to maintain, relatively cheap, less hazardous and the problems of pollution in electrical power has been eliminated in the solar energy (Website, 2007). To address these problems up front the demand for traffic light controller becomes necessary and this prompted the emergence of this work (Figure 1).

The traffic light controller is a device that manages free flow of traffics along three, or more road junctions. The device has a sequence selector for red, green, amber and a yellow light that indicates present state of the traffic flow. Here green colored light mean “Go”, which permits entry into the intersection. Red coloured light means “Stop”; which prohibits entry into the junction. Amber light allows entry of traffic but requires clearance of intersection; and, yellow light means “Fault” indicating that there is a fault. Here, the yellow light will remain on until the fault is cleared. The device also consists of time base (555 timer), decade counter D-flip flop and relay circuit for switching the appropriate light. The automated traffic light controller was so designed on the basis of electronic instrumentation and experimental techniques in electronic engineering so as to allow more time of traffic flow for more busy roads across the junctions while less time for less busy roads, as others remain stand still to avoid collision. The traffic light controller ensures that the waiting vehicles/motorcycles are not unnecessarily delayed. This traffic light controller is capable of successfully managing the flow of traffics at the Sahuda road junctions in Mubi North in Adamawa state, Nigeria.

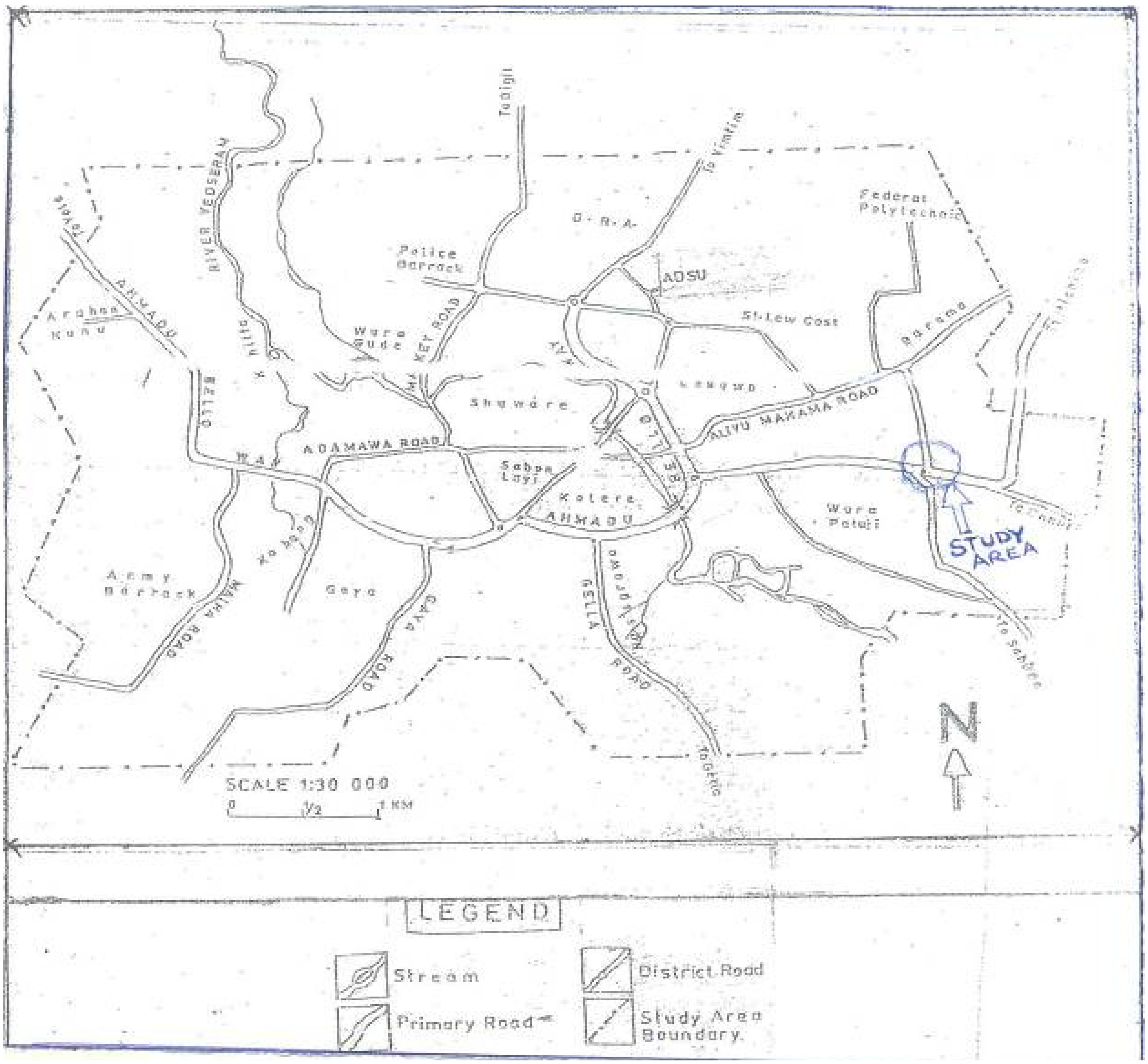

Figure 1. Map Mubi showing road network and the study area.

THEORY AND DESCRIPTION OF ELECTRONIC COMPONENTS USED

Power supply

The design used 12V rechargeable battery and solar panel from sunlight. The circuit consist of oscillator and a regulator transistor, the solar energy charge the battery when sunlight is bright enough. A diode is required between the panel and the battery as it leak 1 mA from the battery when it is not illuminated (Website, 2007).

The regulator transistor is designed to limit the output to 12V; this voltage will be maintain over the capability of the circuit, the transistor oscillator is a high current type as it is turned ON for a very short time of period to saturate the core of the transformer. The energy is then released as a high voltage pulse. These pulses are then passed to the electrolytic capacitor and appear as a 12V supply as a supply to the traffic light controller circuit. The supply can be made automatic by adding a 1 KΩ resistor and diode (INA 148) as in Figure 2(a). When the power supply is connected to the main circuit it starts operation satisfactorily (Frank, 2004) and circuit is further simulated as shown in Figure 2(b) to ascertain the technical function of the circuit.

The oscillator

The 555 timer was used in the design as a stable mode

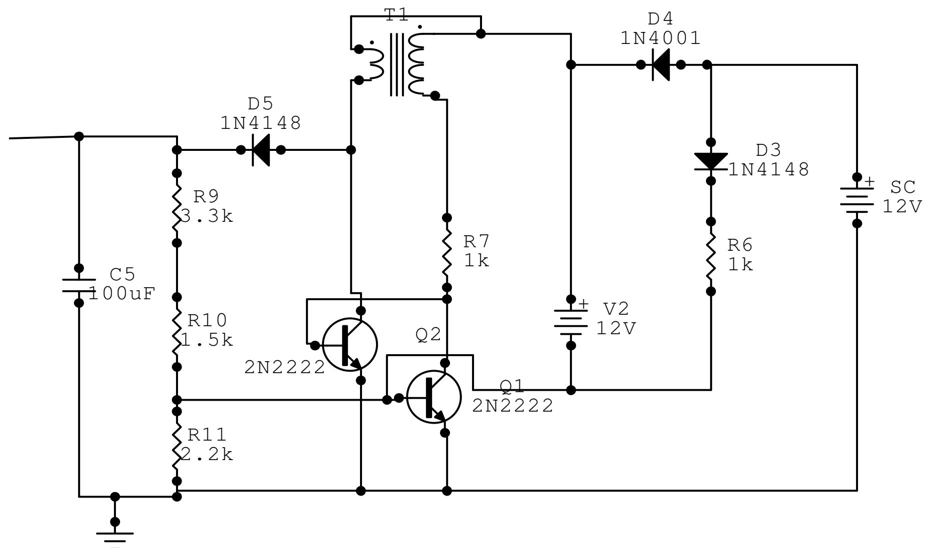

Figure 2(a). Solar energy power supply unit.

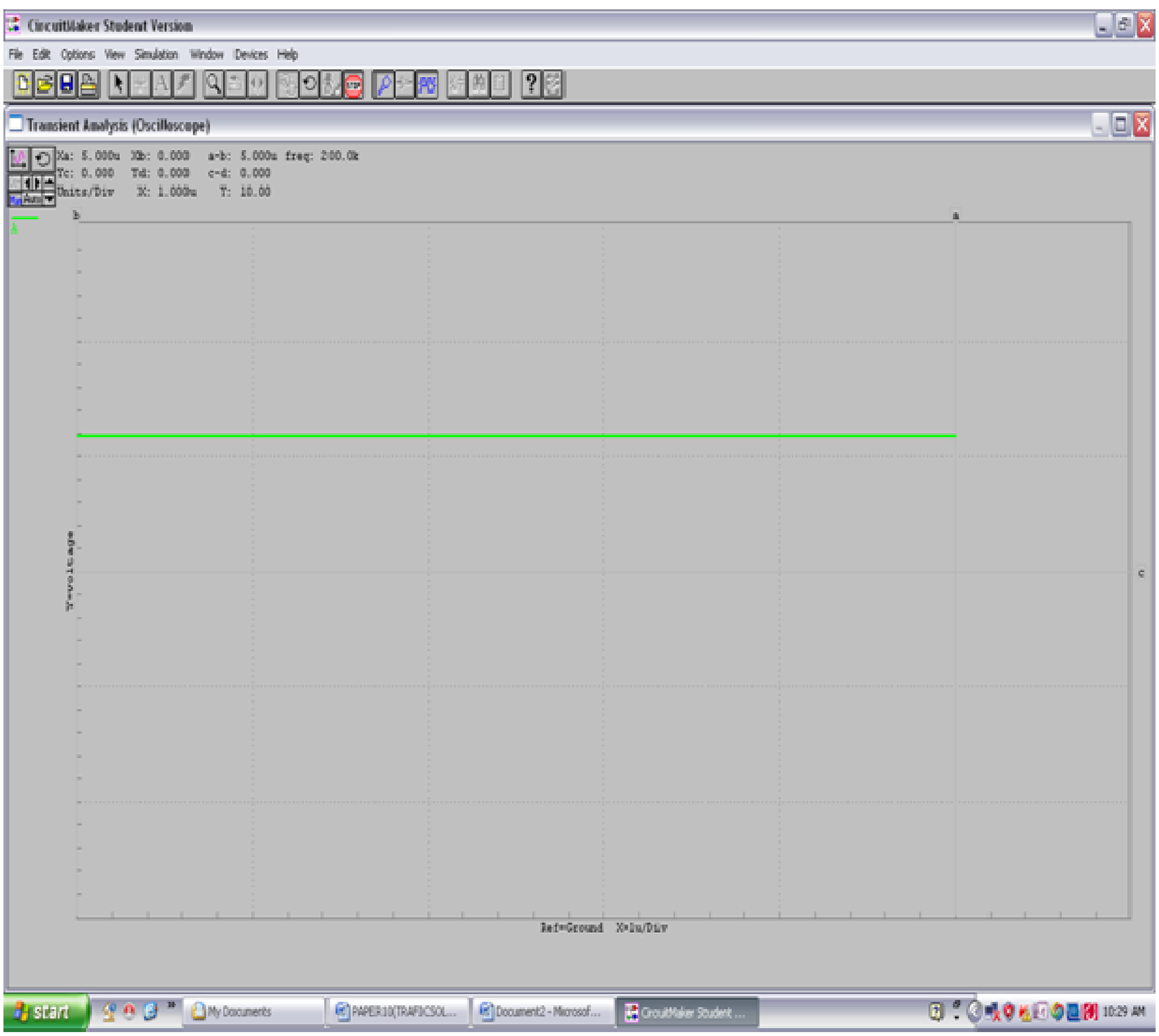

Figure 2(b). Simulated result of solar energy power supply (DC output Voltage).

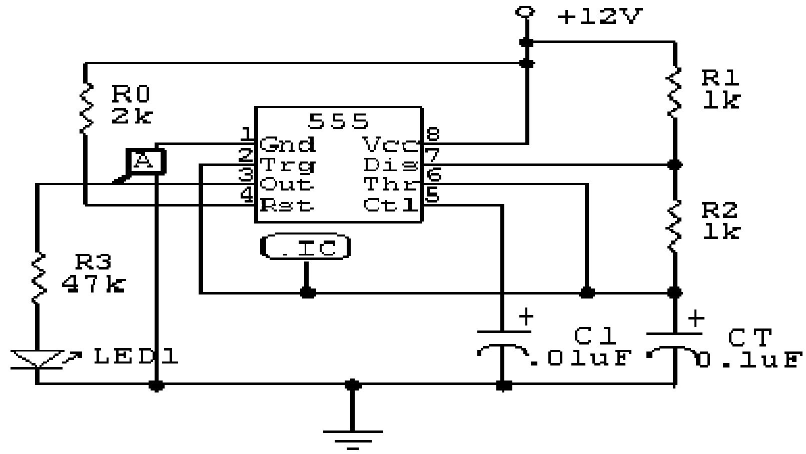

Figure 3(a). An oscillator circuit.

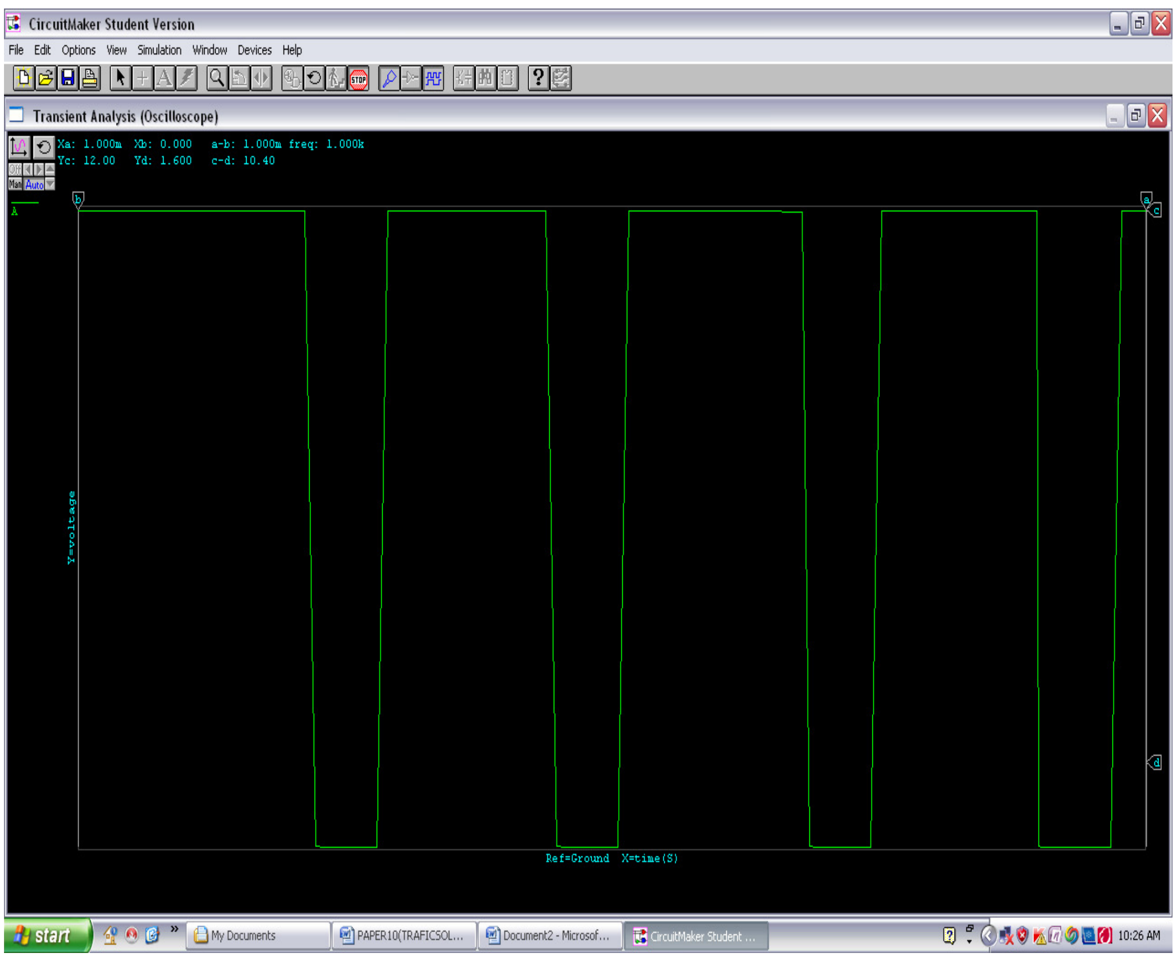

Figure 3(b). Simulated result of an oscilator circuit.

configured to operate as a multivibrator as shown in Figure 3a. The oscillator generates pulse by charging and discharging the capacitor C such that the charging time is given by

$$T_1 = \ln 2\ (R_1 + R_2)\ C_1 \quad (1)$$

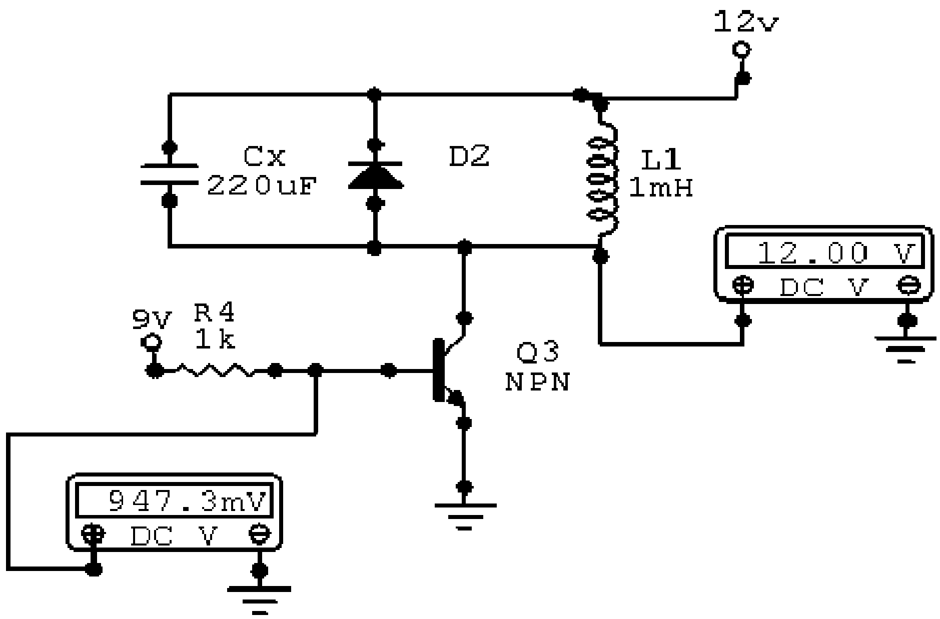

Figure 4(a). Switching and Interfacing circuit.

Similarly the standard discharging time is given by (Paul, 1995)

$T_2 = \ln 2 R_2 C_1$ (2)

Where the T_1 and T_2 stands for the charging and discharging time respectively (Tony, 2001; Ronald, 2001).

The total period taking by the capacitor to charged up completely and discharged is given by

$T = T_1 + T_2$ (3)

So that the frequency of the oscillation can be computed using the following expression as (Ali, 2007)

$$F = \frac{1}{T} \quad (4)$$

Indicator stage

The indicator stage consists of resistor R_3 and diode D_1 as shown in Figure 3a. Here the diode D_1 becomes "on" only when the clock pulse is generated. The value R_3 was obtained using simple ohm's law, given by

$$R_3 = \frac{V_{cc} - V_d}{I_d} \quad (5)$$

Where V_d is the diode drop; Vcc is the supply voltage I_d is the diode current (Charles, 1979; Loveday, 1984) and circuit is simulated as shown in Figure 3(b).

Switching/interfacing circuit

The switching circuit as shown in Figure 4a is built on an NPN transistor with a β = 40; where β represents the gain of NPN transistor, applying Kirchoff's voltage Law to the circuit it yields.

$$V_{CC} - I_B R_B - V_{BE} = 0$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} \quad (6)$$

$$I_C = \beta I_B \quad (7)$$

Where I_B is the base current; β is the current amplifier and I_c is the collector current is controlled by base current (Jones, 1993; Hughes, 2004).

The interfacing circuit

The interfacing circuit in Figure 4(a) simply involves interfacing the switching circuit through the relay to the signal that indicates traffic flow controller condition at any particular point in time. The relay has two double contacts which are connected to the Red and Green light while the other double contact is connected to Amber and yellow

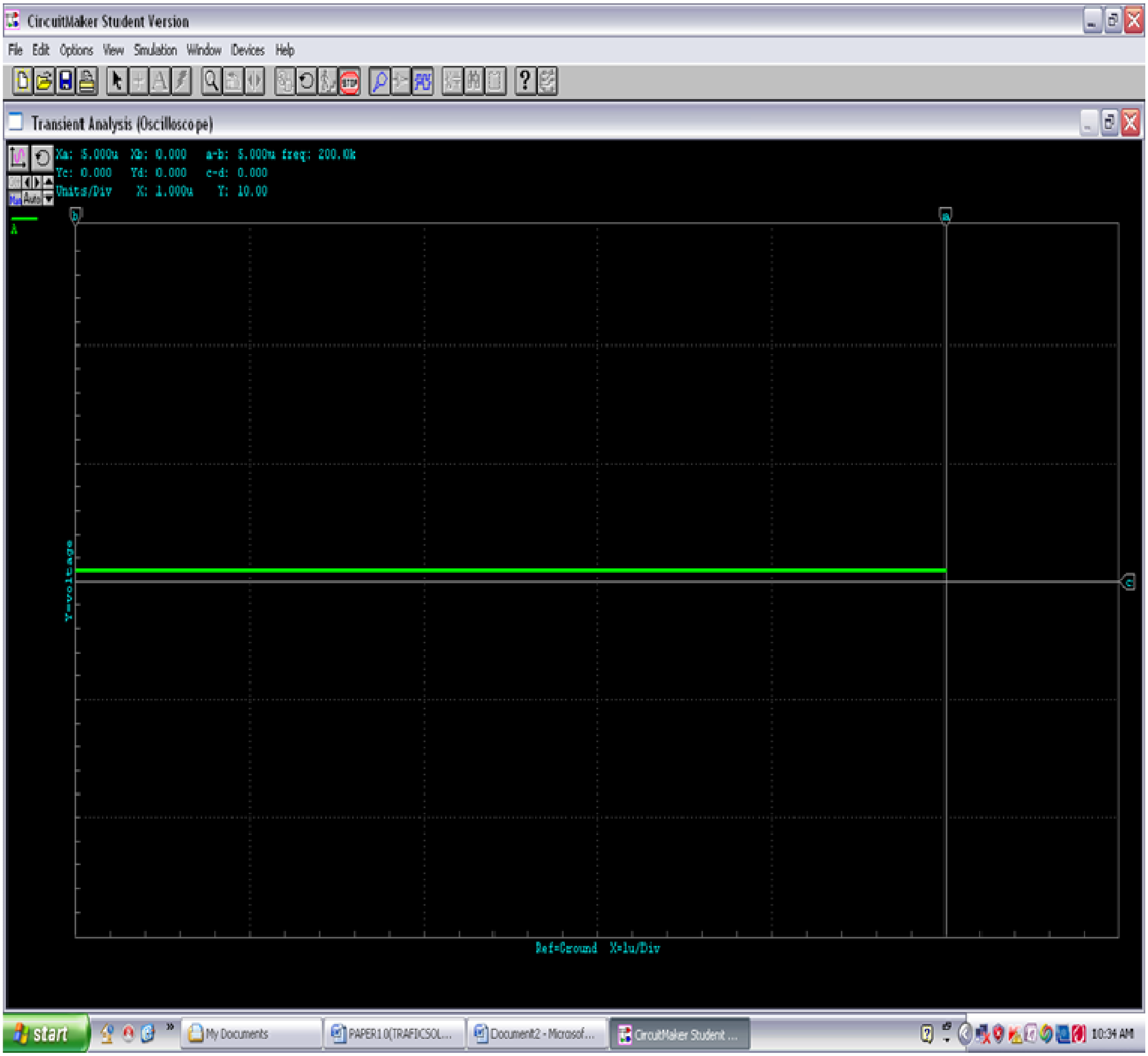

Figure 4(b). Simulated result of Switching and interfacing circuit (DC voltage).

light. On the double contact relay, the Red is connected normally to the closed path and Green to the opened path. When energized as a result of the transistor conducting at that instant, the Red path and the other path will open for the green light to come on. Similarly the other double contact will be energized for the Amber to come up when the transistor is conducting, (Morley, 1994; Ralph and Richard, 1992) and circuit is simulated as shown in Figure 4(b).

The counter circuit

The counter circuit as shown in Figure 5 is built on an IC (4017). Such that when the reset (pin 15) of the counter is taken HIGH, the counter will make the output “0” to go HIGH (1). When ‘CLOCK INHIBIT’ pin 13 is taken to HIGH, the counter will FREEZE on the output that is currently HIGH. The reset (pin 15) is connected to the supply via R5 and C3 to the earth, the reset is achieved

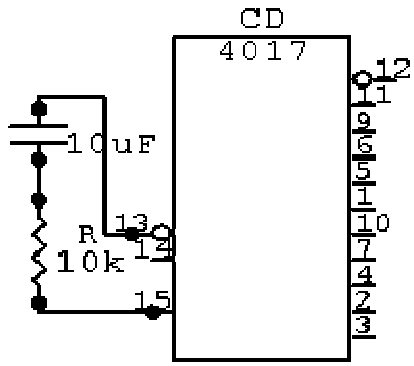

Figure 5. Counter circuit.

when C3 is supplied; since voltage across the capacitor cannot change instantaneously this makes the voltage across it to be zero. C3 then start to change and when fully charged creates an open circuit making R5 to take (pin 15) to ground; this process continues for the twenty (20) counting sequence (Onohaebi, 2006; Theraja and Theraja, 1997).

DESIGN PROCEDURES

The design of the automated traffic light controller circuit took the following stages; as shown in Figure 6.

Power supply

The only component that has to make in the transformer, is the core of a 20 mH choke is used and re-wound with two winding and remove the five winding, the first winding is 60 turns and the ends are connected to the pins at the end of the core. The other winding is 35 turns and has flying leads on the board. The 35 turns winding must be connected in a special way to provide a positive voltage to the base of the oscillator transistor, the operation of the circuit itself depend on the direction of the winding relative to the other.

The oscillator

The value of the capacitor C that generated a pulse by charging and discharging was computed using Equation (1) as 225 μF with T_1 = 3.5s, R_1 = 1 kΩ and R_2 = 10 kΩ. But for practical purposes, the value of the capacitor C_1 chosen from data book was C_1 = 220 μF as the nearest available value (ECG, 2000). The time (T_2) taken for the capacitor C_1 to be discharged was computed using Equation (2) as 1.5 s and the frequency of the oscillation of the signal from Equation (4), was also computed to be 0.2 Hz.

Indicator stage

The value of R_3 was computed from Equation (5) as R_3 = 10 kΩ with V_d = 2V and I_d = 10 mA.

Switching circuit

The transistor base current was obtained from Equation (6) as I_B = 10mA with V_{cc} = +12V, V_{BE} = 0.7V and R_B = 10 KΩ while the collector current was computed from Equation (7) as I_c = 0.04A since β = 40.

MATERIALS AND METHODS

The materials used for the design and its component rating is as follows 12V automated solar energy power supply; Diodes IN4001; Capacitors as filters; IC regulator (KA 7812); Oscillator (555 timer) as astable, +12V; Counter (V_{cc}=12V), +12V; Switching circuit consist of indicator with 12V, 20 mA and R=320Ω, NPN transistor (h_{fe}=40, V_{be}=0.7V); capacitor 220μf and diode at V_{cc} = 12V; Interfacing circuit with relay type Jzc20 (4088), 10A, 12V DC with coil resistance of 320 Ω and Stop watch

Method of data collection

The traffic volume at the busy four - ways junction along sahuda Road in Mubi North, Adamawa state Nigeria was observed and documented at two-hourly intervals from (6:00 am - 10:00 pm) daily for the period of one week. The resulting volume of traffic across the junction obtained from the field survey was tabulated as shown in Table 1.

Methods of design

The method employed in the design was an adaptation of the standard traffic light controller, although in this design the power supply utilizes an automated solar energy instead of the know electrical power supply that is more generally used in Nigeria.

In this work, a modeled area controlled by the traffic light was constructed on wooden board (100 cm in length and 70 cm in width), which shows the landmark of the four-ways junction. The direction of the traffic flow and the respective traffic light poles were erected on the side of each road. The height of the standard poles is 30 cm with holes were drilled to fix the bulb at the top end of the poles made of timber wood.

The test carried out involved the operation of the controlled traffic light model and observation of each bulb. In the test, the “on or off” times for each bulb are the corresponding “1 or 0” shown in Table 2.

Operational principle of the traffic light controller

When the system is powered on, the oscillator starts producing pulses, which are used to clock the counter. The outputs of the counter are fed into a logic AND Gate selectively in a D flip-flop circuit. The output of the gate switches the bipolar transistor, which controls the light through the relays. The light is then addressed through the relay as it switches ON while the others remain OFF.

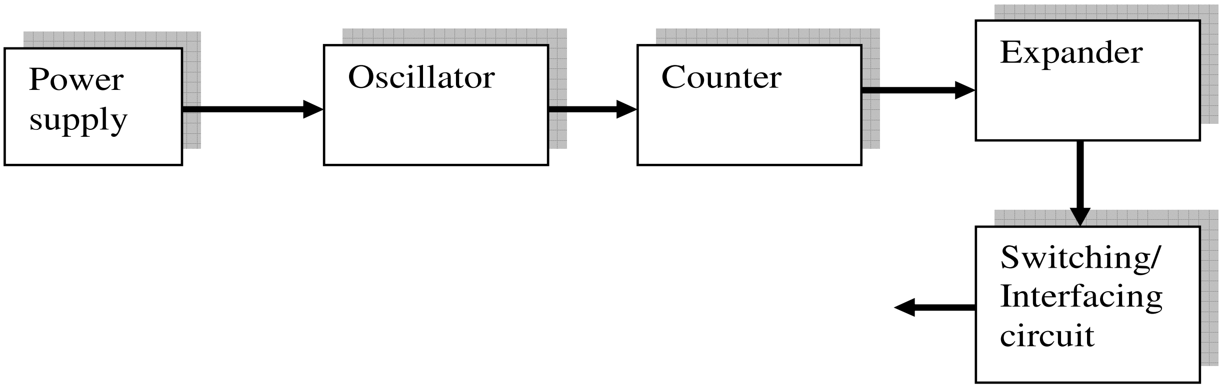

Figure 6. Block diagram of traffic light controller.

Table 1. The average volume of traffic across the four-way junction.

Time	Sahuda	Masalchi	Stadium	Sarki
6-8 am	100	180	90	10
8-10 am	420	586	480	30
10-12 noon	318	310	324	20
12-2 pm	207	182	200	17
2-4 pm	188	206	192	32
4-6 pm	412	571	418	12
6-8 pm	218	233	222	11
8-10 pm	80	100	70	06
Total	1982	2368	1996	138

Source. Field survey, 2007.

Table 2. Traffic light controller transmission of the designed model.

Sarki Rd.	Stadium Rd	Sahuda Rd	Masalachi Rd
RAGY	RAGY	RAGY	RAGY
1 0 1 0	1 0 0 0	1 0 0 0	1 0 0 0
0 1 1 0	1 1 0 0	1 0 0 0	1 0 0 0
1 0 0 0	0 0 1 0	1 0 0 0	1 0 0 0
1 0 0 0	0 0 1 0	1 0 0 0	1 0 0 0
1 0 0 0	0 0 1 0	1 0 0 0	1 0 0 0
1 0 0 0	0 1 1 0	1 0 0 0	1 0 0 0
1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0
1 0 0 0	1 0 0 0	0 0 1 0	1 0 0 0
1 0 0 0	1 0 0 0	0 0 1 0	1 0 0 0
1 0 0 0	1 0 0 0	0 1 1 0	1 1 0 0
1 0 0 0	1 0 0 0	1 0 0 0	0 0 1 0
1 0 0 0	1 0 0 0	1 0 0 0	0 0 1 0
1 0 0 0	1 0 0 0	1 0 0 0	0 0 1 0
1 0 0 0	1 0 0 0	1 0 0 0	0 0 1 0
1 1 0 0	1 0 0 0	1 0 0 0	0 1 1 0

R = Red light, A = Amber light, G = Green light, Y = Yellow light, 1 = ON, 0 = OFF.

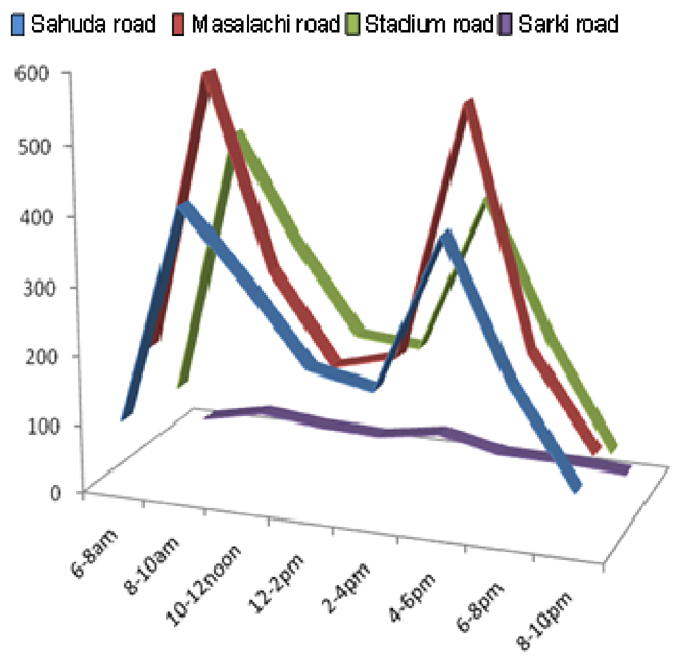

Figure 7. An analysis of average volume of traffic across the four – way junctions.

RESULTS AND DISCUSSION

Figure 7 presents the average volume of traffic across the four-way junction in Sahuda road Mubi town. The observations of vehicular traffic at the junction made for the period of one week revealed that Masalachi road has the heaviest vehicular flow (2368) , followed by Stadium road (1996), Sahuda road (1982) and lastly with Sarki road (138) having the lowest flow (with just 6 ± 0.2% of the highest flow). The traffic light controller was designed in such a way that more time is given to busy roads while less time for less busy road accordingly. The maximum time given to roads based on vehicular traffic flow follows: Masalachi road (17.50 s), stadium road (14.00 s),

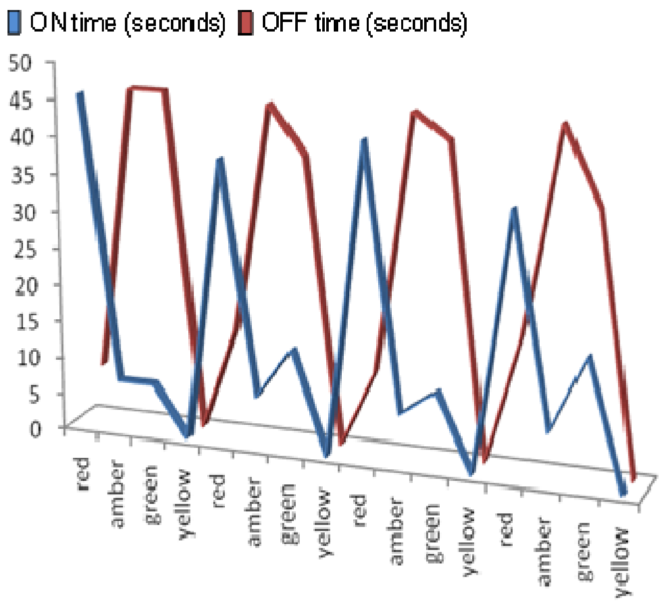

Figure 8. An analysis of timing for the traffic light controller.

Table 3. Simplification of timing traffic light controller.

Signal (Head)	Colored Bulbs	On Time (sec)	Off time (sec)
Sarki road	Red	45.50	7.00
	Amber	7.00	45.50
	Green	7.00	45.00
	Yellow	0.00	0.00
Stadium road	Red	38.50	14.00
	Amber	7.00	45.00
	Green	14.00	38.50
	Yellow	0.00	0.00
Sahuda road	Red	42.50	10.50
	Amber	7.00	45.50
	Green	10.50	42.00
	Yellow	0.00	0.00
Masalachi road	Red	35.50	17.50
	Amber	7.00	45.50
	Green	17.50	35.00
	Yellow	0.00	0.00

Sahuda (10.50 s) and Sarki (7.00 s).

Table 2 shows that each count of the controller had duration of 3.5 s after which a transmission was made to the next count. The transition of the counter from one count to another is continuous until the last count sequence was reached after which the counter returns to the start count again. There are fifteen (15) counts in all, implying that each count sequence has duration of 52.5s, based on this, the timing for the traffic light controller was developed for the four roads intersection at the four way - junctions as presented in Figure 8. The 3.5 s was chosen to ensure that sufficient number of waiting vehicles /motorcycles are passed.

This model has achieved simplification of timing for traffic light controller as shown in Table 3. Here the ON time and OFF time were computed based on the numbers of 1's or 0's with each count representing 3.5 s while 0 represents no time. In Masalchi road for instance there are five 1's. Therefore the ON time is (17.5 s) while the OFF time is 35.00 s making a total of 52.5 s. This was also applied to the other roads junction; for Stadium road ON time is 14.00 s, OFF time is 38.50 s; for Sahuda road the ON time is 10.50 s, while OFF time is 42.00 s; and Sarki road ON time is 7.00 s, OFF time 45.50 s.

Figure 9 compares the design value and practical value recorded when the test of the model was carried out as shown in Table 4. The test carried out involved the operation of the controller and observation of each bulb. In the test, the "ON and OFF" times for each bulb are the corresponding "1 or 0" with an insignificant error in reading of ± 0.05 counted in some values as shown in Table 5. This value of error has no effect on the efficiency of the system since it is very negligible.

The break down of the traffic light controller transmission design values in abnormal situation presented in Table 6 revealed that Red light of the traffic controller was completely ON for the whole 52.5 s while Yellow light flashes in every 3.5 s indicating the presence of faults in the traffic light controller.

Figure 10 gives the simplification of the traffic light controller in abnormal condition meaning that when any fault is developed in the traffic light controller, the Red light is completely ON for the period of 52.50 s while OFF will become 0.00, consequently, the Yellow light will keep flashing continuously at an interval of every 3.5 s, with an ON time of 24.50 s, while OFF time becomes 28.00 s. Here the Amber and Green lights will have their ON time as 0.00 seconds and OFF is 52.50 s.

Conclusion

The design of automated traffic light controller was achieved successfully with the help of automated solar energy power supply, 555 timer connected in astable mode, decade counter, relay circuit and timing sequence selector for red, green, amber and yellow light. The Yellow light was also used in the circuit to indicate presence of faults in the automated traffic light controller. The automated 12V solar energy power supply.

The traffic light controller was developed to allow more time for busy roads while less busy roads attracted less time; this model was designed, implemented and tested with a satisfactory operation and performance efficiency.

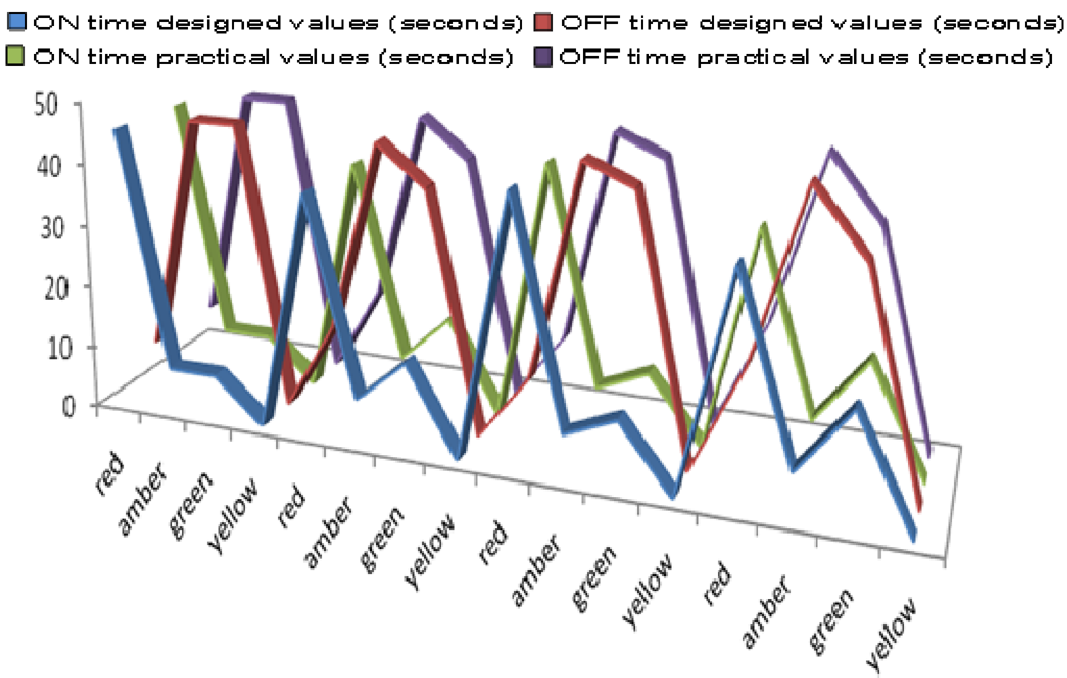

Figure 9. An analysis of the timing for each bulb.

Table 4. Break down of the timing for each bulb**.**

Signal (head)	Colored bulbs	Designed values		Practical values	
		On time	Off time	On time	Off time
Sarki road	Red	45.50	7.00	45.50	7.00
	Amber	7.00	45.00	7.00	45.50
	Green	7.00	45.50	7.00	45.50
	Yellow	0.00	0.00	0.00	0.00
Stadium road	Red	38.50	14.00	38.50	14.00
	Amber	7.00	45.50	7.00	45.50
	Green	14.00	38.50	14.50	38.00
	Yellow	0.00	0.00	0.00	0.00
Sahuda road	Red	42.50	10.50	42.50	10.00
	Amber	7.00	45.50	7.00	45.50
	Green	10.50	42.00	10.50	42.50
	Yellow	0.00	0.00	0.00	0.00
Masalachi road	Red	35.50	17.50	35.00	17.50
	Amber	7.00	45.00	7.00	45.50
	Green	17.50	35.00	17.50	35.00
	Yellow	0.00	0.00	0.00	0.00

It is recommended that further improvement on the system may be required to incorporate a device that can rectify the fault immediately, in case such situation occurs. This model will certainly eliminate the inefficiency associated with human traffic controller, also minimized incessant accident and unnecessary traffic jams at

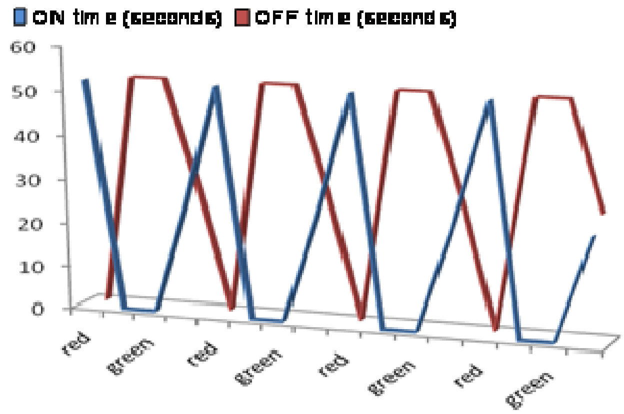

Figure 10. An analysis of traffic light in abnormal condition.

Table 5. Traffic light controller transmission design values in abnormal condition.

Sarki Rd.	Stadium Rd	Sahuda Rd	Masalachi Rd
RAGY	**RAGY**	**RAGY**	**RAGY**
1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
1 0 0 0	1 0 0 0	1 0 0 0	1 0 0
1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0
1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0
1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0
1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0
1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0
1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0

junctions in developing countries.

Table 6. The simplification of the traffic light in abnormal condition

Signal (Head)	Colored Bulbs	On time (sec)	Off time (sec)
Sarki road	Red	52.50	0.00
	Amber	0.00	52.50
	Green	0.00	52.50
	Yellow	24.50	28.00
Stadium road	Red	52.50	0.00
	Amber	0.00	52.50
	Green	0.00	52.50
	Yellow	24.50	28.00
Sahuda road	Red	52.50	0.00
	Amber	0.00	52.50
	Green	0.00	52.50
	Yellow	24.50	28.00
Masalachi road	Red	52.50	0.00
	Amber	0.00	52.00
	Green	0.00	52.00
	Yellow	24.50	28.00

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