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Full Length Research Paper

Design and implimentaton of a model (ATLC-2007DNM) of an automated traffic light controller

Danladi A.[1], Ndatuwong L. G.[1] and Malgwi D. I.[2]

[1]Department of Physics, Adamawa State University, Mubi, Nigeria.
[2]Department of Physics, University of Maiduguri, Nigeria.

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In this work, a model of an automated traffic light controller (ATLC –2007DNM) had been designed and implemented, using electronic instrumentation and experimental techniques in electronic engineering and physics, to manage the traffics at the busy four- ways junctions along Sahuda road in Mubi North, Adamawa State, Nigeria. The designed was achieved with the help of low power transformer rating of 3.6 watts, 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 (ATLC – 2007DNM) to allowed 17.50s, 14.00s, 10.50 and 7.00s 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 word: Traffic light, four-way junction, traffic jam.

INTRODUCTION

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 and physics 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.

Study area and justification

Mubi is the second largest town in Adamawa state of Nigeria, it lies between latitude 9^0 $30^|$ and 11^o North of the equator and longitude 13^o and 13^o $34^|$ east of Greenwich meridians, Mubi has a land area of $4728.77KM^2$ 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 lead 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. To address these problems up front the demand for traffic light controller

*Corresponding author. E-mail: deshalangs3g@yahoo.com

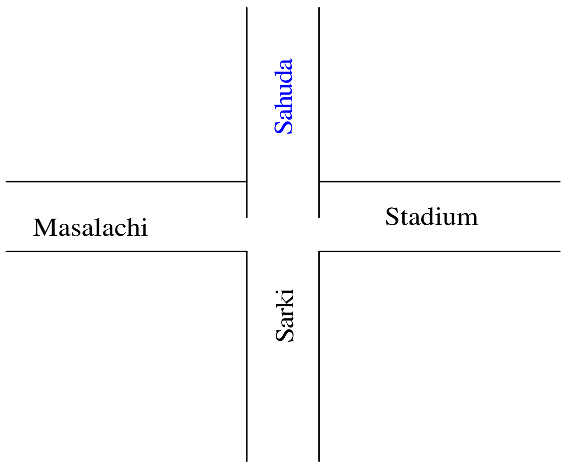

Figure 1. 4-way junction(Sahuda road)

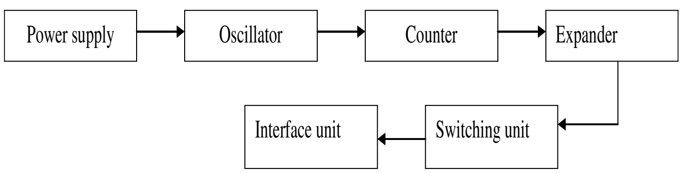

Figure 2. Block diagram of traffic light controller

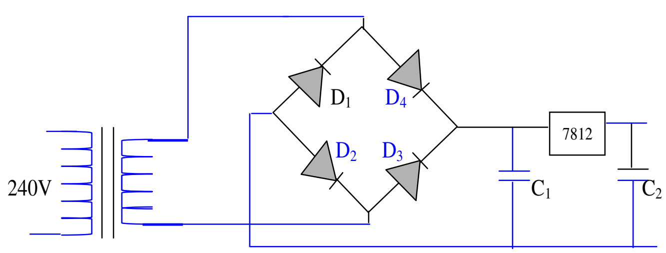

Figure 3. Power supply circuit diagram. D_1-D_8, IN 4001 rectifier diode C_1-220 μF, 50V capacitor, C_2-10 μF, 16V capacitor, 7812, +12 V regulators.

becomes necessary and this prompted the emergence of this work (Figure 1).

THEORY AND DESCRIPTION OF ELECTRONIC COMPONENTS USED

Power supply

The power supply used in the design incorporates an integrated circuit (Ics), regulator that has a fixed voltage regulator producing +12V. While the specification of the transformer is a 240 V a.c. input and 12V output as shown in the Figure 3. The rectifier is a full wave bridge rectifier, made up of four rectifier diodes of the required rating of 2V. The a.c. voltage output is filtered by a 50V,

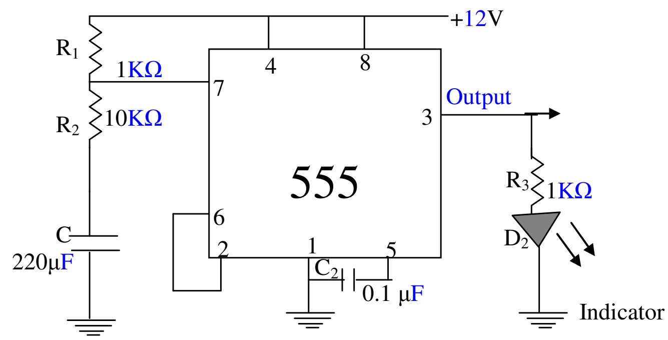

Figure 4. Oscillator circuit.

220 μF capacitor which is fed to the input of a 12 V regulator (KA 7812) via 50V, 10 μF smoothing capacitor, as to remove ripples in the signals that could cause error in the IC component used.
The transformer rating was determined using equation (1)

$$P = IV \quad (1)$$

Where P is the power rating of the transformer, V is the output voltage of the transformer and I is the transformer current (Frank, 2004).

The primary current in the transformer can be computed using equation (2) given by

$$I_pV_p = I_sV_s \quad (2)$$

Where p and s here mean primary and secondary windings of the transformer respectively (Nolan, 2004).

The oscillator

The 555 timer was used in the design as a stable mode configured to operate as a multivibrator as shown in Figure 4. The oscillator generates pulse by charging and discharging the capacitor C such that the charging time is given by

$$T_1 = \ln 2 \, (R_1 + R_2) \, C \quad (3)$$

Similarly the standard discharging time is given by

$$T_2 = \ln 2 R_2 C \quad (4)$$

Where the T_1 and T_2 stands for the charging and discharging time respectively (Tony 2001 and Ronold, 2001). The total period taking by the capacitor to charged up completely and discharged is given by

$$T = T_1 + T_2 \quad (5)$$

So that the frequency of the oscillation can be computed using the following expression as (Robert, 1999)

$$F = \frac{1}{T} \quad (6)$$

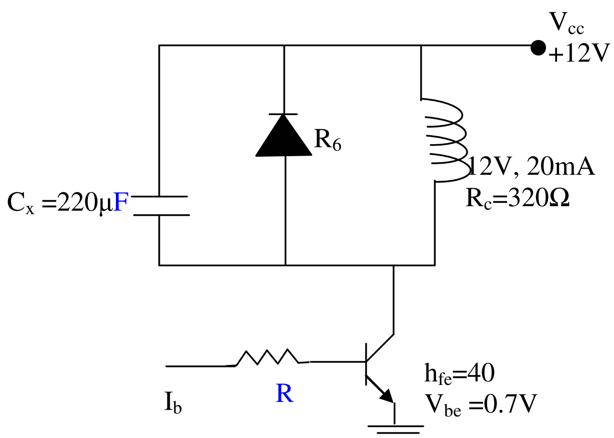

Figure 5. Switching circuit /interfacing circuits.

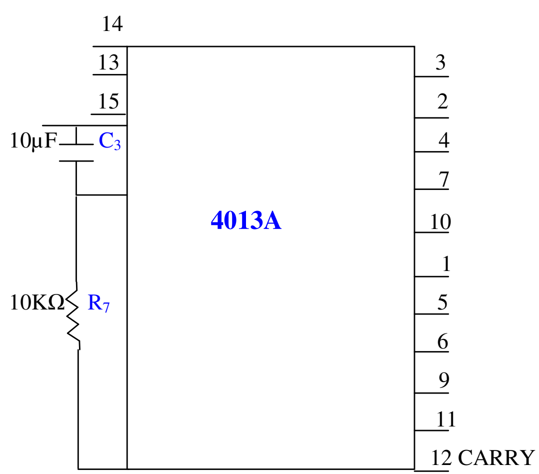

Figure 6. Counter circuit

Indicator stage

The indicator stage consists of resistor R_3 and diode D_2 as shown in Fig 4 Here the diode D_2 becomes "on" only when the clock pulse is generated. The value R_3 was obtained using simple ohm's law, given by

$$R_3 = \frac{V_{cc} - V_d}{I_d} \quad (7)$$

Where V_d is the diode drop; Vcc is the supply voltage I_d is the diode current (Loveday, 1984).

Switching/interfacing circuit

The switching circuit as shown in Figure 5 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.

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

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} \quad (8)$$

$$I_C = \beta I_B \quad (9)$$

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 counter circuit

The counter circuit as shown in Figure 6 is built on an IC (4013A). 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 R_7 and C_3 to the earth, the reset is achieved when C_3 is supplied; since voltage across the capacitor cannot change instantaneously this makes the voltage across it to be zero. C_3 then start to change and when fully charged creates an open circuit making R_7 to take (pin 15) to ground; this process continues for the twenty (20) counting sequence (Onohaebi, 2006; Theraja and Theraja, 1997).

The interfacing circuit

The interfacing circuit in Figure 5 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 contact which is connected to the Red and Green light while the other double contact is connected to Amber and yellow 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; Raiph and Richard, 1992)

DESIGN PROCEDURES

The design of the automated traffic light controller circuit took the following stages as shown in |Figure 2.

Power supply

The power rating of the transformer was computed using equation (1), as 3.6W with current (I) rating of 300 mA and output voltage of 12 V. While the primary current (I_p)

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

Time	Sahuda	Masalchi	Stadium	Sarki
6-8 am	100	180	90	10
8-10am	420	586	480	30
1012Noon	318	310	324	20
12-2Pm	207	182	200	17
2-4Pm	188	206	192	32
4-6Pm	412	571	418	12
6-8Pm	218	233	222	11
8-10Pm	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

of the transformer was also computed using equation (2) as 22 mA.

The oscillator

The value of the capacitor C that generated a pulse by charging and discharging was computed using equation 3 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 chosen from data book was C = 220 μF as the nearest available value. The time (T_2) taken for the capacitor C to be discharged was computed using equation (4) as 1.5s and, the frequency of the oscillation of the signal from equation (6), was also computed to be 0.2 Hz.

Indicator stage

The value of R_3 was computed from equation (7) as R_3 = 10 kΩ with V_d = 2V and I_d = 10 mA.

Switching circuit

The transistor base current was obtained from equation (8) as I_B = 10mA with V_{cc}= +12V, V_{BE} = 0.7 V and R_B = 10 KΩ while the collector current was computed from equation (9) as I_c = 0.04A since β = 40.

MATERIALS AND METHODS

The materials used for the design and its component rating is as follows; Transformer 240V/12V with the power rating of 3.6W; Diodes IN4001; Capacitors as filters; IC regulator (KA 7812); Oscillator (555 timer) as a stable, +12V; Counter (V_{cc}=12V), +12V; Switching circuit consist of indicator with 12V, 20mA and R = 320 Ω, NPN transistor (h_{fe} = 40, V_{be} = 0.7 V); capacitor 220 μf and diode at V_{cc}=12 V;

Interfacing circuit with relay type Jzc20 (4088), 10 A, 12 Vdc 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 low power rating of 3.6 W instead of the known 4.8 W (Onohaebi, 2006), this will accomplish the same function as the standard traffic light controller.

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 "1or 0" shown in Table 2. The time was measured and recorded in Table 4 using a stop watch.

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.

RESULTS AND DISCUSSION

Table 1 shows that the volume of traffic across the four-

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

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), 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 52.5 s, 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 Table 3. The 3.5 s was chosen to ensure that sufficient number of waiting vehicles /motorcycles are pass.

This model has achieved simplification of timing for traffic light controller. 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 45.50s.

Table 4 compares the design value and practical value recorded when the test of the model was carried out. 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. This value of error has no effect on the efficiency of the system since it is very negligible.

The breakdown of the traffic light controller transmission design values in abnormal situation presented in Table 5 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.

Table 6 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 52.50s.

Conclusion

The design of automated traffic light controller was achieved successfully with the help of a low power rating of 3.6 W, 555 timer connected in a stable 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 traffic light controller was developed to allow more time for busy roads while less busy roads attracted less time; this model was

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

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 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

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	52.50
	Green	0.00	52.50
	Yellow	24.50	28.00

was designed, implemented and tested with a 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 junctions in developing countries.

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