www.coast.osustech.edu.ng
COAST
JOURNAL OF THE SCHOOL OF SCIENCE
Volume 3, Issue 1. June, 2021 ISSN: 2714-3716

Coast, J. Sch. Sci. 3 (1): 542 - 545

SHORT COMMUNICATION

DEVELOPMENT OF A LED ELECTRONIC DNA MODEL

[*1]Oke, A. O., [1]Ehiabhili, J. C. and [2]Arowolo, O. K.

[1] Department of Physics, Federal University Oye-Ekiti, Ekiti State.
[2] Department of Biology, Elizade University Ilara-Mokin.
*Corresponding author's email address: aduragbemi.oke@fuoye.edu.ng.

Abstract

There are different kinds of deoxyribonucleic acid (DNA) models which has been based on the use of paper, candy, beads, and Styrofoam balls. In this paper, a model has been developed using a water hose as the backbone and strands; light-emitting diodes (LEDs) were arranged in the backbone and strands to indicate reaction between adenine with thymine, and between guanine with cytosine. The lighting of the LEDs was controlled by sending pulses from the microcontroller and switched with transistors. The anode and cathode of the LEDs is powered with TIP42 and BD140 respectively taking a signal from the microcontroller. The heat emitted is below room temperature if left for 24 hours. The power consumption of the entire circuit is about 15W. This model is better used in teaching over other previous model as it uses LEDs to indicate the interactions of the nucleotides.

Keywords: Deoxyribonucleic acid (DNA), light emitting diode (LED), microcontroller, adenine, thymine, guanine, cytosine, and transistor.

Introduction

Introduction

The availability of the DNA model for instruction both at higher institutions of learning and colleges will be an advantage for the effective teaching of genetics. Genetics is a branch of biology gives a detailed explanation of genes. It justifies what they are, what they do, and how they work (Travers and Muskhelishvili, 2015) The focus of this paper is not geared towards the biological theories of genetics, but to see how the deoxyribonucleic acid (DNA) structure can be designed using the knowledge of electronics. However, it is essential to mention a few of these biological terms for better clarification to corroborate the physics behind the development of this model.

The molecules inside the nucleus of a cell are summed up to be gene. These genes are made of DNA, which is divided into separate pieces called chromosomes (Gregory*et al.*, 2006; Bacolla *et al.*, 2013). All chromosomes contain four nucleotides, cytosine (C), guanine (G), adenine (A), thymine (T), arranged in sequence to make a long string as well as a monosaccharide sugar called deoxyribose and a phosphate group (Thanbichler and Shapiro, 2006). The bond of formation between the nucleotides is a covalent bond between the sugar of one nucleotide and the phosphate of the next, resulting in an alternating sugar-phosphate backbone. Adenine interacts with thymine and guanine interacts with cytosine. The two interactions are terminated with the monosaccharide sugar and the phosphate group (i.e. DNA backbone). More than a few DNA models made before this model had been made either by using paper, candy, beads, Styrofoam balls, majorly for sale purposes (Painter, 1922; Armstrong, and Jones, 2003). No model has been made using a 10 mm LED. The focus of this electronic DNA model was to develop a structure of about 6ft high with LEDs of different colours showing the interactions earlier discussed.

Materials and Method

The block diagram of the LED DNA model is shown in Figure 1. The power block supplies 5 V to the microcontroller block and the LED block containing the backbone and strands of the DNA ladder. The LED block contains Transistors and LEDs. The Transistor serves as a voltage amplifier for the arrays of the LEDs. The microcontroller sends a control signal to the transistors which lights the LEDs.

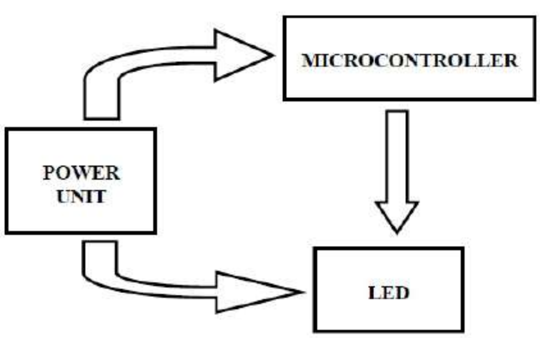

Figure 1: Block diagram of the LED electronic DNA model

The structure of a DNA structure is like a twisted ladder. In constructing the electronic DNA structure, water hose were used for the skeletal structure of the ladder. A 10 mm diameter water hose was used both for the backbone and the strands. The length of the backbone of the DNA was measured to be 6ft and the length of the strands was 25 cm each.

The10 mmLEDs of different colours are to be inserted into the water-hose. The LEDs were soldered parallel in groups taking the colours into consideration (blue with blue, green with green, and red with red, yellow with yellow). The LEDs are arranged such that the total current of all LEDs does not exceed the supply voltage and current to the circuit. In that wise, the number of LEDs connected together were considered. Fifteen LEDs were connected in parallel both for the strands and backbone respectively (Mehta and Rohit, 2008; Mazidi,2006).

Table 1: Standard Technical Data Table for 10mm LED

Colour	$I_F$max.(mA	V_FTyp (V)	$V_F$max (V)	$V_F$min. (V)
Green	20	3	6	3
Red	20	2	5	2
Yellow	20	2	5	2
Blue	20	3	6	3

From Table 1, taking the maximum current to be 20 mA and 5 V from the power supply, the limiting resistance value for fifteen (15) LED strands is about 17 ohms. This is done to control and minimize the current through the LEDs in order to avoid damage to the LEDs.

The input signal from the microcontroller is applied to the base of the transistor, and the output is taken between the collector and emitter (Figure 2). The output of the transistor connects directly to the anode of the LEDs (Babalola, 2006).

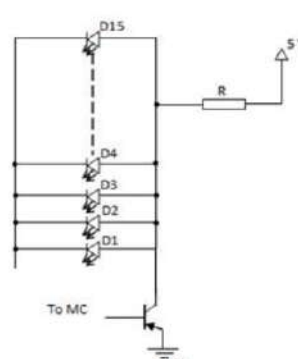

Figure 2: Common Emitter Connection

The Microcontroller (MC) sends pulses to the transistors at different times. The first pulse sent goes to the base of the three TIP42 transistors used. Each TIP42 is connected to the anode of the array of LEDs. The second signal goes to the base of the entire BD140 transistor used from different pins but with the same pulse (same delay time). A five seconds (5 s) pulse is sent to the backbone of the DNA model through the three TIP42 transistors. At this time the LEDs of the strands are OFF for the same 5 s. a second pulse is sent to the strands through BD140 transistors. The toggling of the LEDs of both the backbone and the strands is done to minimize the power consumption and reduce the heat dissipated from the voltage regulators and the transformer (Figure 3)

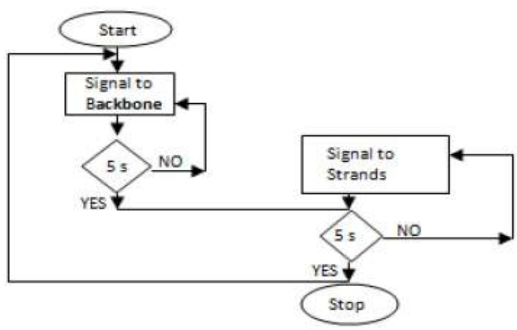

Figure 3: Flowchart showing the toggling of the LEDs

The maximum output current of the LM7805 voltage regulator is 1.5A. Connecting the anodes of about 200 LEDs to the output of the voltage regulator will sink a current of about 4A, which is more than what the regulator can supply, and so leads to heating of the regulator, which can damage the regulator in a short time. For this cause, the current is shared between three LM7805 (Mehta and Rohit, 2008). The output of each regulator is connected to the emitter of TIP42 and the collector of each TIP42 supplies the anode of the LEDs in the three categories.

In preventing the over-heating of the diodes used in the rectifier circuit, a 12-0-12 V, 1.5 A transformer was connected to two diodes to obtain a full-wave rectification. The Peak Inverse Voltage (PIV) or the Peak Reverse Voltage (PRV) of a centered-tap transformer full-wave rectification is twice the peak voltage (V_m) of the transformer secondary voltage. The PIV is the maximum allowable voltage that the diode can safely withstand without breakdown. It is the maximum instantaneous voltage that occurs during the negative half cycle. The value of PIV is extremely important when a diode is used as a rectifier. It is an important factor considered when selecting a diode for a power supply. If the reverse voltage across a P-N junction diode exceeds its PIV, the reverse current increases sharply and breaks down the junction because of the excessive heat generated (Mehta and Rohit, 2008).

Results and Discussion

After all the connections and soldiering, the groups of LEDs inserted into the water-hose. The water-hose-containing LEDs was joined together to form a ladder. The ladder was twisted to the shape as presented in Figure 4. All the LEDs were connected to the main circuit and tested.

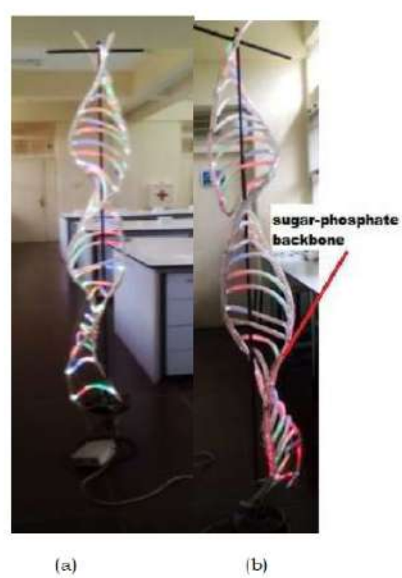

Figure 4: Picture of the DNA Model

After the power was switched ON, power was supplied to every section of the LEDs. Remember that the LEDs represent nucleotides which are adenine, thymine, guanine and cytosine. The red colour shown in Figure 4 (a) and (b) indicates the sugar-phosphate backbone of the DNA. The reaction between colour blue and yellow in the middle of the DNA gives information about the reaction between Adenine and Thymine. Also, the reaction between colour red and green show the reaction between Guanine and Cytosine respectively. The DNA model is left for about three hours at the first test to see the different interactions of the DNA. The current and voltage consumed are about 3 A and 4.7 V respectively. The heat dissipated is normal – below room temperature. Consequently, the feedback from student after the model was demonstrated compared to the paper, beads, and Styrofoam balls models they have been exposed to was better. The interactions is better seen with the lightings of the LEDs.

Conclusion

DNA model presented in this paper has proven to be well suitable for teaching in Biological laboratories of institutions and colleges. The use of LEDs of different colours to indicate the reaction of the interaction made it easier for students to understand the concept of DNA. The power consumption of the model is about 15 W.

Acknowledgment

I acknowledge the assistance rendered by Mr. Arowolo O.K. in analyzing the DNA concept.

References

Armstrong, S.J. and Jones G.H. (2003). Meotic cytology and chromosome behavior in wild-type Arabidopsis thaliana, *J. Exp. Bit*, 54:1-8.

Babalola, M.T., Ewetumo T., Adenugba D.A. and Olasoji M.O. (2004), Electronic practical manual, 16 - 24

Bacolla, A., Cooper, D.N. and Vasquesz, K.M. (2013). DNA structure matters, *Genome Medicine*, 5: 51-61.

Gregory S.G., Barlow K.F., McLay K.E., Kaul R., and Swarbreck D. (2006). The DNA sequence and biological annotation of human chromosome 1, *Nature,* 441: 315-322.

Mazidi, A. Mazidi (2006). *8051 Microcontroller and Embedded systems,* (prentice Hall), 1-20.

Mehta, V.K., and Rohit, Mehta (2008). Semiconductor diode, *Principle of electronics*, (S. Chand & Company, RAM NAGAR, NEW DEKHI-110 055), 91–93.

Painter T.S. (1922). The spermatogenesis of man, *Anal. Res.*, 23: 129-137.

Thanbichler M. and Shapiro L. (2006). Chromosome organization and segregation in bacteria, *J. struct. Biol.,* 156: 292-301.

Travers A. and Muskhelishvili G. (2015). DNA Structure and function, *FEBS*, 282: 2279 2285.