CHARACTERIZATION OF A PH TEST STRIP BASED ON RGB HUE REFLECTANCE

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ABSTRACT

The study is about the construction of a palm-sized pH test strip reader (6.25inx3.75inx2in) employing four tri-chromatic LEDs for the LED driver, four phototransistors for detector, and GizDuino as processor and the controller. This device is handheld, quite simple but very reliable in obtaining accurate pH level output using the pH test strips. This device showed an outstanding performance in reading out the pH levels of different kinds of solutions tested using the test strips on the given ranges it can cover; 0-14. The device shows that the colors on each test strip pad has its own HSI values which varies based on the RGB values of each pad. It also shows that the increase in pixel values of the RGB is caused by the increase in current and voltage. Also, the increase in voltage has the same reaction with the increase of current. This device has a guaranteed precise output, is easy to reproduce and comes with a low production cost.

Keywords: pH, pixel, tri-chromatic LED, phototransistor.

INTRODUCTION

It is important to know whether a liquid is acidic or basic in determining its uses. The enzymes in stomach liquids, which are acidic, aid in digestion. The strong acidic or basic nature of toilet bowl cleaners promotes effective cleaning. The acidity of automobile battery fluids makes the production of electrical energy possible. The above examples illustrate positive uses for acidity and/or alkalinity. Sometimes there is too much of one or the other and problems arise as a result. For example, if our stomachs are too acid, we get a stomachache. It is important for children to understand the idea that liquid substances may have these characteristics and that certain effects may result [1].

This nature of liquid, whether basic, acidic or neutral is measured by a quantity called pH. This pH stands for “potential of hydrogen” which refers to the concentration of hydrogen ions in a solution sampled. The measurements are ranged from 1 to 14. 1 is the most acidic and 1 the most basic. The pH 7 is said to be neutral. Although, the pH scale are in terms of 10. Meaning, if a solution is pH 6, it is ten times more acidic than pH 5 [2].

There are different kinds of ways to measure the pH level of a solution. PH test strips, litmus papers or pH papers are commonly used since it is easily obtained and it has low cost. The color of the wetted sample is matched to the color on a color chart to infer a pH value. PH paper is typically used for preliminary and small volume measuring. It cannot be used for continuous monitoring of a process because of the possibility of process solutions that can interfere with the color change. Another way is the use of a colorimeter. A vial filled with a certain volume of solution is added with a reagent. When the reagent is added, the color of the solution will change then compared to a color wheel or spectral standard to interpolate the pH value. This is commonly used in determining the pH value of water in swimming pools, spas, cooling towers and boilers. It can also be used in seas, lakes and river waters. But these give approximate and don't guarantee precise measurements.

Using pH meter is the one recommended for precise and continuous measuring. Most laboratories use a pH meter connected to a strip chart recorder or some other data acquisition device so that the reading can be recorded or stored electronically over a user-defined time range.

There are pH testers and meters already existing used to obtain the value of pH values. Though these testers are reliable, the problem with these is that these testers are high-cost and the parts or components used in the device have low-availability. Also, these testers use liquid solutions for testing.

Another device that was developed before which contributed to this study is the urine test strip reader. This research is entitled "Novel optical absorbance-based multi-analytes detection module using a tri-chromatic LED, PDs and plastic optical fibers and its application to a palm-sized urine test strip reader" by Lee Dae-Sik, Mun Yeon Jung, Byoung Goo Jeon and Mi-Jin Sohn. This device reads test strips with three pads and uses urine for tests. They also use phototransistors and RGB LED and optical fibers in addition.

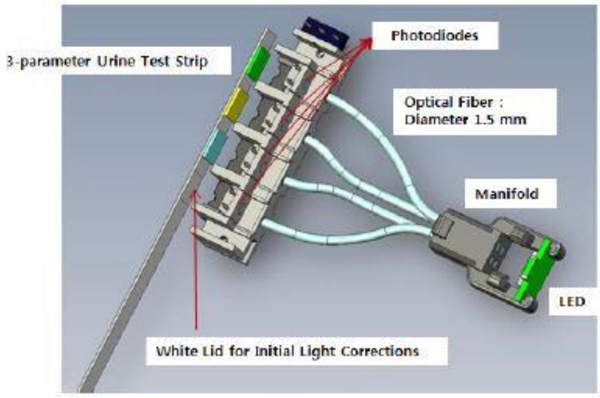

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Figure 1 Urine Test Strip Reader Representation [3]

This study aims to develop high-reliable, easy to troubleshoot, low-cost device that detects pH value through test strips with four pads

RESEARCH DESIGN

Conceptual Framework

Tri-chromatic LEDs are used in this study, programmed to light in sequence that will reflect to the pad of the test strip. The phototransistor now will detect the light coming from the pad; the data from the phototransistor will be evaluated by the program in the GizDuino showing how much voltage and pixel values the pad is.

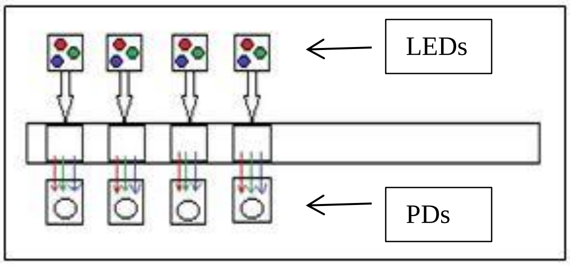

Figure 2 Representation of Device (*pictural representation*)

The light guide in the figure is actually a divider. The divider is made to give each pad equal light that will represent the value of pixels.

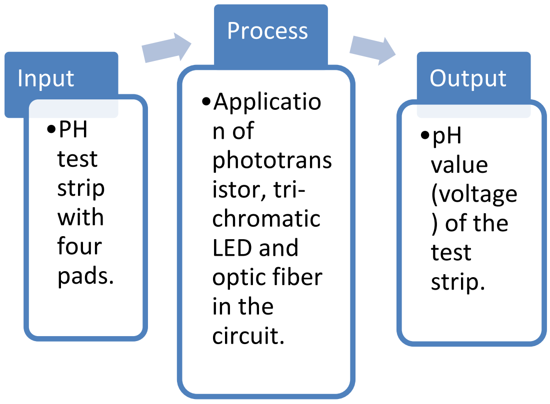

Figure 3 Conceptual Framework

Figure 2 shows that the input of the device is a pH test strip (with four pads). The device will process each pad and the output will be measured in pixels and voltages.

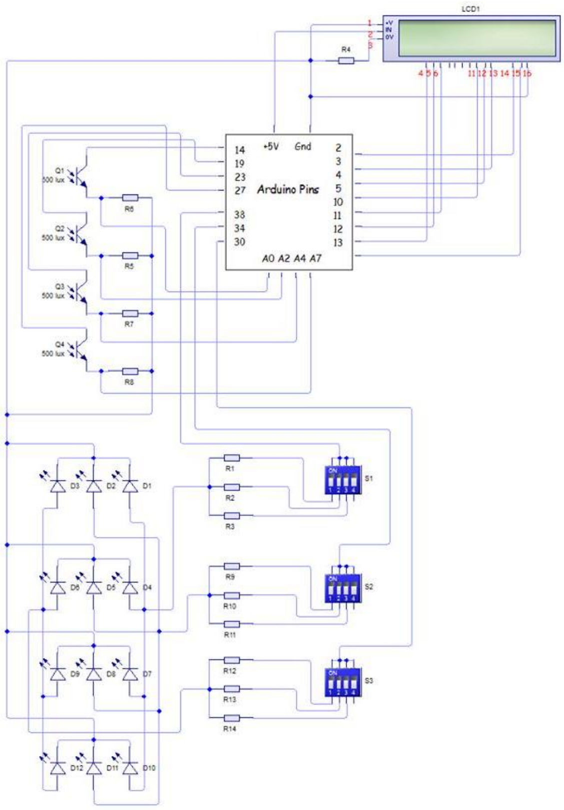

Figure 4 Schematic Diagram of the Device

Figure 4 shows the connection of each component of the whole device, consisting of the major ones: three DIP switches for the current switching from 10mA, 20mA and 50mA; four phototransistors and tri-chromatic LEDs; Gizduino X ver 2.0 for the microcontroller and LCD Display for the output.

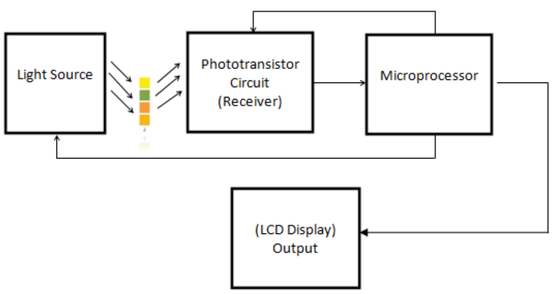

Figure 5 Block Diagram of the System

A. Light Source – This will light up the pH test strip

pH 7			
	Red(V)	***Green(V)***	***Blue(V)***
Pad 1	0.93939	1.0365	1.09612
Pad 2	1.1375	1.04757	0.69224
Pad 3	0.64125	0.88563	0.27102
Pad 4	0.7408	0.3695	0.16504

B. Phototransistor Circuit - phototransistor reads the data of the test strip received from the test strip which reflected from the LED

C. Microcontroller - interpret the data and convert from pixels into RGB values.

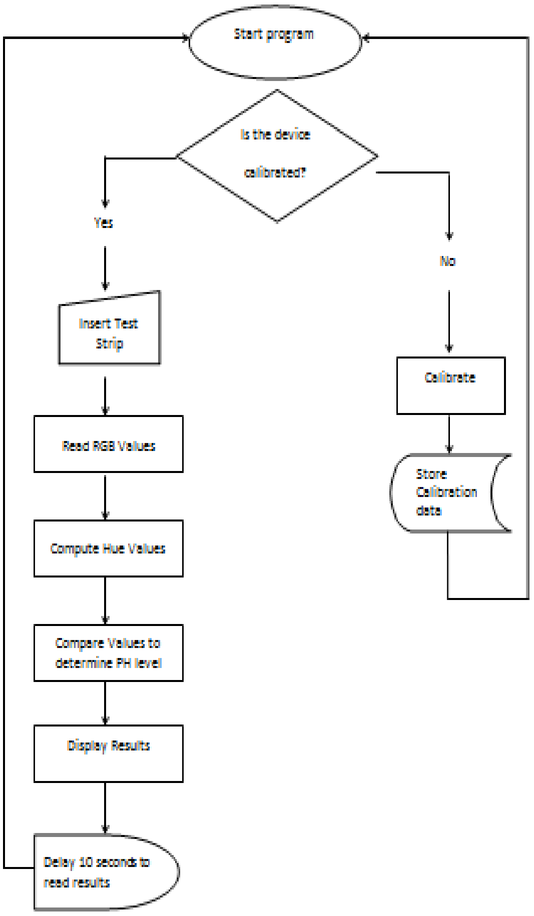

Figure 6 Process Flowchart

The program is developed to read four pads of the test strip all at once. The processor is programmed to identify the input data and transfer the output to the LCD. This program will display the outputs with flow of: RGB values (pixels) > hue values (pixels) > RGB values (voltage).

D. Output- This is an LCD Display that will show the pH value of the test strip which is the same with the universal indicator.

Figure 7 Inside the Device

RESULTS AND DISCUSSION

TABLE 1. pH 4 RGB Voltage Value for 20mA

pH 4			
	Red(V)	***Green(V)***	***Blue(V)***
Pad 1	1.0595	1.052	1.13392
Pad 2	1.1401	1.0323	0.65803
Pad 3	1.0942	0.9638	0.2781
Pad 4	0.8268	0.3346	0.18133

TABLE 2. pH 7 RGB Voltage Value for 20mA

TABLE 3. pH 10 RGB Voltage Value for 20mA

	pH 10		
	Red(V)	***Green(V)***	***Blue(V)***
Pad 1	0.97109	1.0458	1.12087
Pad 2	1.13001	0.9218	0.65722
Pad 3	0.41496	0.6509	0.32209
Pad 4	0.76132	0.3561	0.17351

TABLE 4. pH 4 RGB Pixel Value for 20mA

	pH 4			
	Red	***Green***	***Blue***	***Hue***
Pad 1	216.767	215.233	232	249.667
Pad 2	233.267	211.2	134.633	46.9
Pad 3	223.867	197.2	56.9	50.5
Pad 4	169.167	68.466	37.1	12

TABLE 5. pH 7 RGB Pixel Value for 20mA

	pH 7		
	Red(V)	***Green(V)***	***Blue(V)***
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Pad 2	1.1401	1.0323	0.65803
Pad 3	1.0942	0.9638	0.2781
Pad 4	0.8268	0.3346	0.18133

TABLE 6 pH 10 RGB Pixel Value for 20mA

	pH 10			
	Red	***Green***	***Blue***	***Hue***
Pad 1	198.5	213.967	229.33	209.06
Pad 2	231.2	188.6	134.467	34.5
Pad 3	84.9	133.167	65.9	103.067
Pad 4	155.767	72.867	35.5	18.667

The voltage of the RGB in each pH is a variation on how much light does the phototransistor receives. In pH 4 the 3rd pad has light complex of red-orange, in pH 7 the 3rd pad has the complex of green and in pH 10 the 3rd has complex of blue. Based on the table I (pH 4 RGB Voltage Value for 20mA) the red have the higher rate of voltage and in table II (pH 7 RGB Voltage Value for 20mA) the green has. The pixel values of the colors in each pad simply shows how much that color is within the pad. As the voltage and/or pixel of the color increases with respect to the pad, the color's complexion of that pad is the one clearly detected by the phototransistor.

TABLE 7. F-ratio

	F-Ratio			
	Red	***Green***	***Blue***	***Hue***
20mA	0.166	0.1203	0.0009	0.0007

TABLE 8. P-value

	P-Value			
	Red	***Green***	***Blue***	***Hue***
20mA	0.85	0.888	0.999	0.999

Analysis of variance is gathered from the pixel values of the RGB and Hue of each current 10mA, 20mA and 50mA. From the pixel value, the F-ratio is calculated and then the P-value is identified through the use of software, p-value calculator and a table. The F-ratio's null hypothesis means there is no difference between the groups of samples. In this case, the pixel value which is the sample does not vary with the current – the groups. If the null hypothesis is true, you expect F to have a value close to 1.0 most of the time. A large F ratio means that the variation among group means is more than you'd expect to see by chance. F-statistic is a ratio of the mean square and the degree of freedom; using three groups which are the three values of current and also fifteen observations, which are the readings per pad per color.

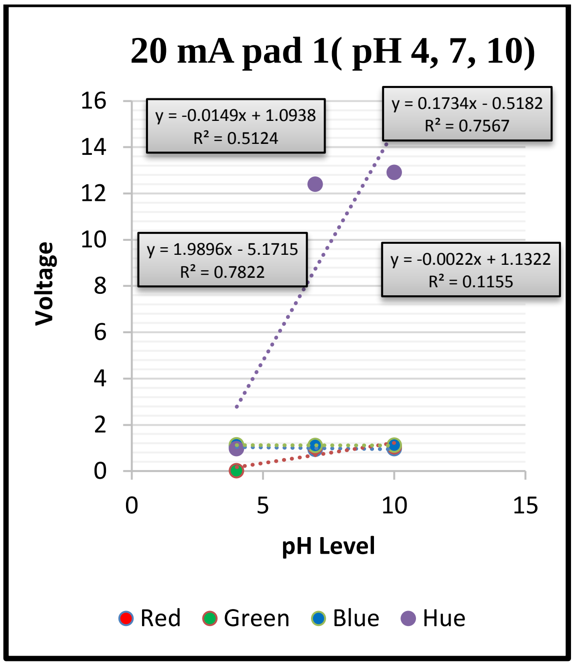

Figure 8i. Graph for 20 mA pad 1 (pH 4, 7, 10)

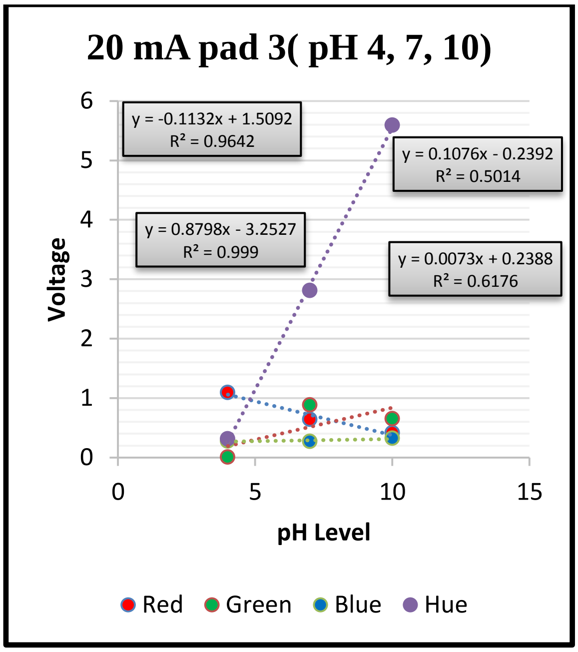

Figure 8iii. Graph for 20 mA pad 2 (pH 4, 7, 10)

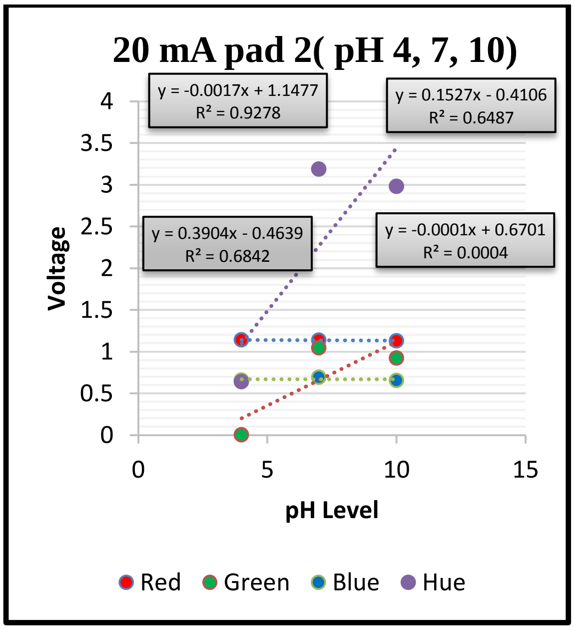

Figure 8ii. Graph for 20 mA pad 2 (pH 4, 7, 10)

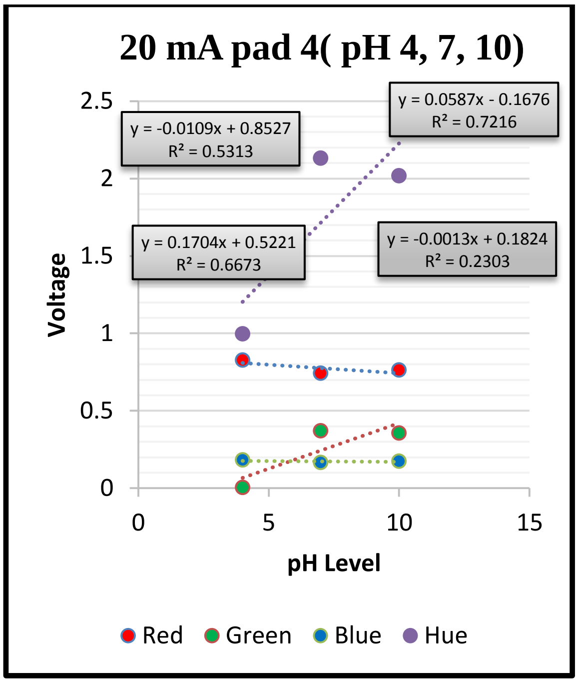

Figure 8iv. Graph for 20 mA pad 2 (pH 4, 7, 10)

The graphs shows the difference of the colors of the pad on each pH level. Based on the graphs the voltage diffres on the color of the pads. The higher the volatge of the pad of the pH the brighter that color indicate the color of the pad. The formula used to gather the coefficient of correlation (R) is

$$\mathbf{r} = \frac{n\sum xy-(\sum x)(\sum y)}{\sqrt{n(\sum x^2)-(\sum x^2)}\sqrt{n(\sum y^2)-(\sum y^2)}} \qquad [4]$$

where n is the number of pairs of data and x and y corresponds to the x-axis values and y-axis values.

The linearity can be determined using the coefficient of correlation. As the coefficient of correlation reaches -1, stronger negative linearity is obtained. On the other hand, as the coefficient of correlation reaches 1, stronger positive linearity is acquired. The graphs shows weak correlation of the pH, it means there is no strong evidence that color of one pH will vary if the other will vary too.

MATHEMATICAL DEVELOPMENT

Plotting this linear regression line has been indicated the equation of the form is ***Y = a + bX***, where ***X*** is the explanatory variable and ***Y*** is the dependent variable [5]. Y=-0.0109x+0.8527 R^2 = 0.5313, this is one of the linear equation of the graph. The equation is given in the slope-intercept form (y=mx+b). The values of m per graph indicates the ratio of change in voltage to the change in pH levels. It indicates how fast the voltage is changing per increase of pH level. The values of b per graph is the initial voltage values when there is no pH test strip being read. The value of R^2 indicates how much the other variable can explain the other variable.

CONCLUSION

The pH levels obtained in the device is the same compared to the colors on the casing of the pH test strips. The device can read all of the proposed pH levels to be read, specifically 0 to 14.

The data presented based on the several testing shows and proves that each color on the test strip pads have its own HSI values. This varies based on the RGB of the pads. It shows that the increase in the pixel value of RGB on each pad is caused by the higher current, making it directly proportional. The same reaction is observed in the different voltages used. Thus, this pH test strip reader is guaranteed to be reliable in obtaining accurate the pH levels of the solutions being tested.

The coefficient of correlation on pixel reading for Hue of 20mA shows that it has strong positive linearity since the coefficient value ranges from 0.7 to 1. Moreover, the coefficient of correlation for voltage reading for RGB values shows that the linearity varies from weak linearity to strong positive linearity considering that it ranged from 0.02 to 1.

For the calculated probability or the p-value, the significance level (α) used is 0.1 and the result is greater than the significance level, therefore, the null hypothesis, which states that pH level reading does not vary with the current, is true.

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