Measurement of Wavelength of Light Using Maximum Point Algorithm

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Abstract –***The light emitted by a source is not of a single wavelength but is distributed over a range of wavelengths. In certain fields like colorimetry, one needs to work with light of a particular wavelength. The aim of this project is to develop a device that disperses the light from an artificial source and deduces the wavelength of the resulting components of that light. By using simple equipments like prism, stepper motor and microcontroller, the device aims to measure the wavelength of light accurately and economically along with a provision for user-reconfigurabilty.***

Key Words: *LED, Wavelength, Prism, Microcontroller*

1. INTRODUCTION

Light is an electromagnetic wave which occupies about 4% of the electromagnetic spectrum. Being a wave, its wavelength is its defining character determining its energy and color. Light of one color differs from another because they have different wavelengths and hence, are perceived differently by the human eye. An LED is a semiconductor diode which, when applied voltage to, produces light. This light is not of a single wavelength but is distributed within a range, with certain wavelengths present in greater intensity than others. Certain applications in pharmaceuticals and colorimetry need to use light of purely one wavelength. For such applications, we need to disperse light emitted by a source (e.g. an LED) into its component wavelengths by passing it through a prism, and single out light of a particular wavelength. This device uses the property of prism to refract ray of light in accordance to its wavelength. Here the displacement of refracted ray from a fixed point is taken into consideration for detecting its particular wavelength. The two main parts of this project are

1) Detection of maximum intensity point
2) Accurate distance measurement of maximum intensity point from a fixed point.

2. BLOCK DIAGRAM OF SYSTEM

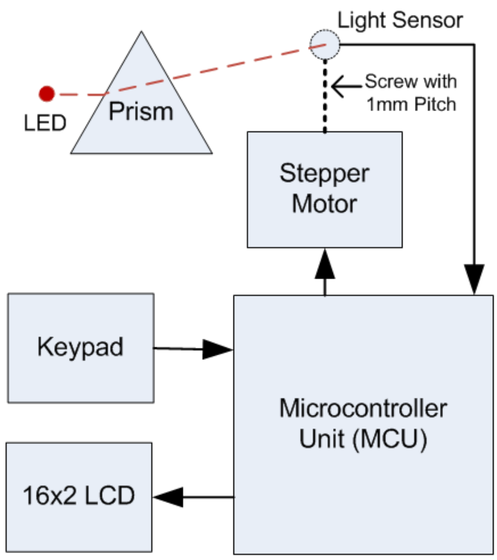

Fig -1: Complete Block Diagram

i) Microcontroller Unit (MCU)
The MCU is the brain of the system. It analyses the incoming data (both analog and digital) and gives an appropriate output. The microcontroller used is Atmel ATMEGA32. This microcontroller is selected due to the following reasons:
• Inbuilt ADC (Analog to Digital Converter),
• Availability of free IDE (Atmel Studio)
• Free C compiler (WinAVR GCC)
• Ease of use and low cost

ii) Keypad
It is a set of keys through which the user interacts with the system. These are digital inputs. The keys include UP, DOWN, ENT and ESC.

iii) 16x2 LCD
This is the display which provides a visual medium through which the user can interact with the system. The detected wavelength is displayed on it.

iv) Prism

This is the most important part of the system. A prism is a transparent optical element with flat, polished surfaces that refracts the light passing through it. The angle of refraction depends on the wavelength of the incident light and the angle of incidence (but here it's kept constant). So, the prism provides a direct relation between angle of refraction and wavelength of light source (See Table 1).

vi) Stepper Motor

A motor is needed to move the sensor in small, equal units. A stepper motor serves this purpose as it moves precisely in accordance with a given number of pulses, so the distance can also be recorded. Here instead of measuring the angle of refraction, the displacement of light from a fix point is measured (See Figure 2).

vi) Light Sensor

This analog sensor reads the intensity of light incident on it. The sensor used in this system is BPW39 which is highly precise and suitable for this application.

vii) LED

This is the light source whose wavelength is to be measured. The LED would be placed in a static assembly so that all the LEDs could be measured with the same calibration. Insead of colored LED, a white soucre with Color Filters an also be used.

3. MAXIMUM POINT ALGORITHM

To find the maximum intensity of light in a particular straight path, an algorithm called maximum point algorithm is used. A graph of Light Intensity versus Displacement Is plotted. The working principle of the algorithm is to find a point where $\frac{di}{ds}$=0 (where i is the value of detected intensity and s is the displacement).

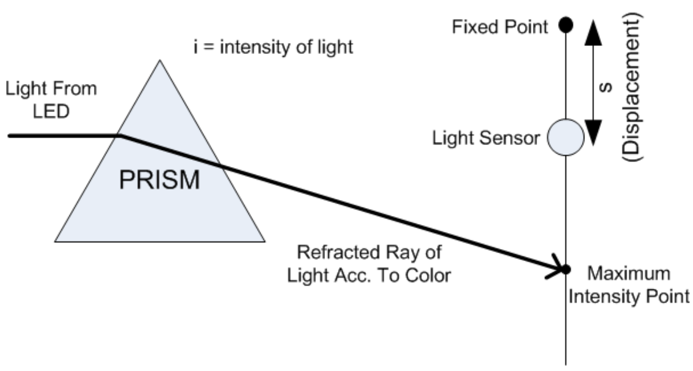

Fig -2: Detailed Block Diagram for Maximum Point Detection

While moving in straight line on the screw (with the help of stepper motor) the sensor takes readings of light intensity at regular distance intervals. The flowchart of the algorithm is given below. Here i_{PREV} is the analog value read at the just previous point and $i_{CURRENT}$ is the analog value currently being read.

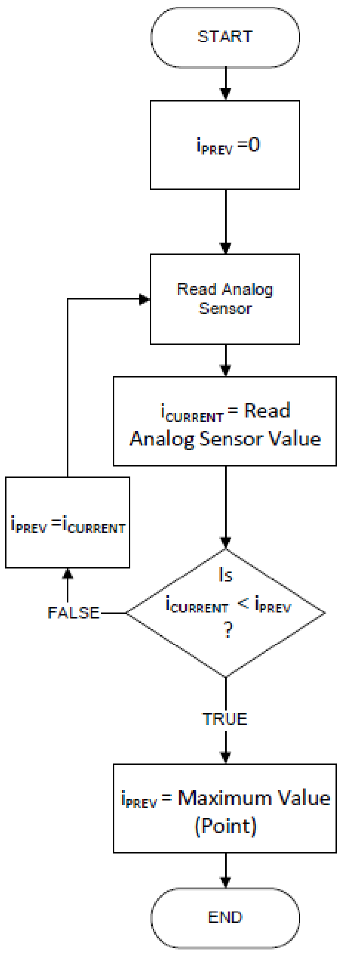

Fig -3: Flowchart of Maximum Point Algorithm

An example given below illustrates the working of the flowchart (See Chart -1):

The intervals on which the readings are taken are marked on the X axis and the light intensity is marked on the Y axis. The algorithm is repeated for each point until we come to a point where the current reading is less than the previous reading i.e. $i_{CURRENT} < i_{PREV}$. i1 is compared to i0, i2 is compared to i1 and so on; until i6=90(<i5) is reached and the loop ends as condition is satisfied (i.e. TRUE) and i_{PREV}=i5=100 is i_{MAX} i.e. the maximum intensity read by the sensor. In this way maximum point algorithm works.

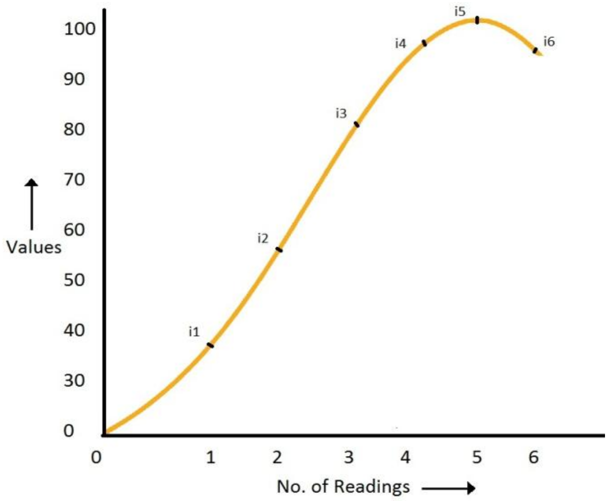

Chart -1: Illustration graph for Max. Point Algorithm

The rate of analog data acquisition, in practice, being very high, the numbers of readings are large and thus errors are avoided.

4. OVERALL WORKING OF SYSTEM

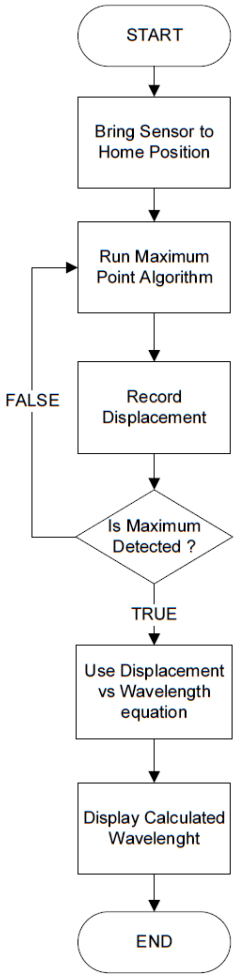

Fig -4: Flowchart of Full Working of System

The detection of wavelength is divided in three parts:

1) Find the Maximum Intensity Point of light on the plane. Let that point be i_{MAX}.
2) Calculate the distance of i_{MAX} point from a fixed point, (This is calculated on the go as the sensor moves).
3) Use the displacement vs wavelength equation to find the unknown wavelength of the LED. This equation is fed into the system by using known LEDs while calibration. (Refer Table -1 and Chart -2)

In this way, the overall system works and after going through the above mentioned steps, the wavelength of LED is displayed on 16x2 LCD.

5. RESULTS

To find the wavelengths of light sources, an equation is needed, so that by putting the value of displacement (s) in it, we get the corresponding wavelength. In order to get that equation, we have to take known wavelength light sources put them in our arrangement and record their displacement. An example is given in Table 1.

s= displacement from fixed point
λ= wavelength of LEDs

	Color	λ (nm)	s (mm)
	Red	633	4
	Orange	612	7
	Yellow	585	9
	Green	560	12
	Blue	470	15
	Indigo	440	17
	Violet	400	21

Table -1: Readings of Wavelength vs Displacement for known wavelengths

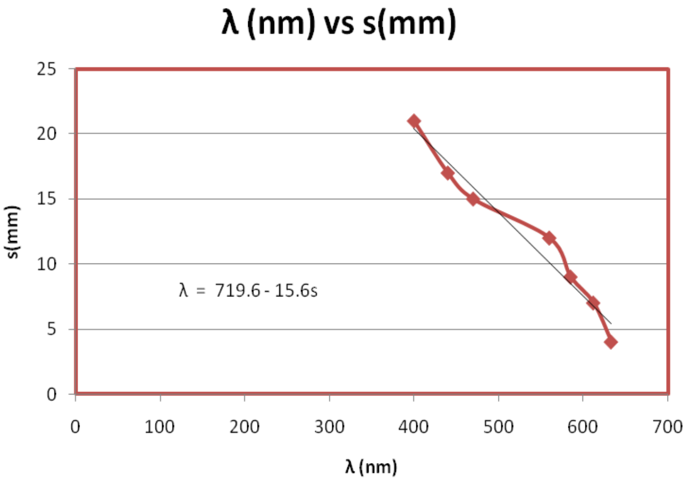

Chart -2: Graph Plotted from data of Table-1

After noting the readings, the data is plotted. Chart-2 shows the graph of data from Table -1. Using **Linear Regression** one can find the equation of plotted data. The equation obtained from this data is

$$\lambda = 719.6 - 15.6s$$

This equation is fed into the system. Thus one can deduce the wavelength of an unknown light source, if the displacement is obtained by putting the source in this arrangement. Like if displacement s = 19mm than wavelength λ = 422nm.

6. CONCLUSION

This project provides the means of measuring the wavelength of light from a source in a simple step-by-step manner. It uses equipment like prism and light sensor which are cheap and easily available. The mathematical technique used i.e. Maximum Point Algorithm, is not cumbersome and is easy to understand. Thus by using simple mathematical tools and physical components, the project develops an economical and user-friendly device to measure the wavelength of light.

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