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Abstract -- The objective of the present paper is to explore an approach of constructing a simple, low cost colour sensor using tri colour RGB model which defines all colours as an additive combination of the primary colours Red, Green and Blue. The sensor consists of a normal Light Dependent Resistor (LDR), surrounded by three Red, Green and Blue LEDs as light source. The LDR and the LEDs are mounted in such a way so that the optical radiation from the LEDs get reflected and falls upon the LDR, the resistivity of which is inversely proportional to the intensity of colour from the LEDs. Therefore, the voltage drop across the LDR is varied whenever the light of different intensities from the LED falls upon it which in turn changes the angular position of the stepper motor. They can be employed for controlling the axial rotation of the stepper motor in robot arm movement to perform some task of manipulation or locomotion under automatic control. The experimental results show that the variation of the resistance of LDR with the change in colour generates an exponential slope and the plot of voltage drop across the LDR with respect to different colour shows a linear slope.

Keywords – Light dependent resistor, Intensity of Colour, Colour Sensor, Signal Conditioning

I. INTRODUCTION

Colour sensor is a device that converts an optical radiation into an electrical signal. Different techniques have been adopted for making colour sensor by using LDR in the past couple of years. Eung Joo, Lee In Gab, Jeong Yang Woo, Park Yeong Ho, Ha Gwang Choon Lee [1] described a method of enhancement of colour of TV picture using RGB sensor which has better visual quality for the view point of the human visual system and reproduces enhanced colour compared to conventional TV. J. Mcdowell, Inc. Aline, Beach Redondo [2] developed a colour sensing system to aid the colour blind using two different colour sensors, a microcontroller, and a display. M.Seelye, G.S Gupta, D. Bailey [3] presented an automated system for measuring plant leaf colour as an indicator of plant health status using low cost Red, Green and Blue (RGB) colour sensors. A colour sensor meant for the radiation-robot was used for the alignment of sample for various experiments in a radiation environment near nuclear beam line of 3MV Tandem Pelletron Accelerator at Institute of Physics, Bhubaneswar by S.Sahu, P.Lenka, S. Kumari, K.B.Sahu and B.Mallick [4]. N.Nasrudin, N.M. Ilis, T.P. Juin, T.T.K. Chun, L.W. Zhe, F.Z. Rokhani [5] constructed a line tracking mobile robot with the capability to follow the white line placed on a horizontal smooth surface lighted by LED and a low cost LDR used as the sensor. A microcontroller based two-axis solar tracking system has been developed with two DC gearboxes motors by Lwin Lwin Oo and N.K. Hlaing [7] in which five LDRs are used to track the sun and to start the operation. Microcontroller-based implementation of the optimal control algorithms for closed loop control of hybrid stepper motor drive has been described by P.Crnosija, B.Kuzmanovic and S.Ajdukovic
Zhang Yajun, Chen Long and Fan Lingyan [11] described the MCU control module and stepper motor drive module to control the position of an elevator based on AT89s52 Microcontroller. Stepper Motors has been chosen as actuators by N.A.Patel, S.N.Pradehan and K.D.Shah [12] to design and realize a two legged robot. The study of adaptive front-lighting system of an automobile based on microcontroller has been discussed by Guo Dong, Wang Hongpei, Gao Song and Wang Jing [13].

In this present paper a low cost LDR based colour sensor has been developed and its application in Stepper Motor Angular Position Control System has been studied to be applied in robot arm control with precise movements. In order to understand the concept of these colour sensors, some physical properties of colour such as wavelength and colour intensity has also been briefly presented. The intensity or brightness of colour is the amplitude of the light wave. The LDR which is a photo resistor is surrounded by three Red, Green and Blue ultra-bright LEDs. By using these three different LEDs, $2^3$ or 8 different combination of colour has been achieved. With these different colour combinations different light intensity has been produced. The working principle of the colour sensor designed depends on the relation between this light intensity and the resistance of the photo resistor (LDR) used. The resistance of the photo resistor (LDR) decreases with the increase of incident light intensity and vice versa. So, if the colour varies, the light intensity also changes, and so the voltage drop across the LDR also changes which has been recorded through a signal conditioning circuitry and is used for the angular position control of a stepper motor. The open loop control unit has been made up of a microcontroller which controls the angular position of stepper motor according to eight different colour combinations sensed by the LDR. The colour sensor system can detect up to 256 colours. Colour sensor is used mostly in digital cameras, camera modules and other imaging device. The application of this method can also be helpful for the robot arm movement. Thus, a Colour sensor of low cost, easy to operate with reasonable accuracy and precision is designed with LDR and LEDs.

II. DESIGNING OF THE COLOUR SENSOR

The colour sensor circuit comprises with a light source (LED) and a detector (LDR). The light source is operated manually. The detector detects the illumination of each coloured ray in terms of resistance of the LDR.

![Image of the Colour Sensor Circuit](image)

As shown in Fig.1, the LDR is surrounded by a Red, a Green and a Blue LED which are connected in parallel to each other. A 5 volt supply is given to glow the LEDs. The combination of Red, Green and Blue colour give eight different colours, among those three are primary colours (Red, Green, Blue), four are secondary colours like (blue+ red), (green+ red), (green+ blue), (Red+ Green +Blue). The LDR and the LEDs are shaded by a piece of White paper so that the light get reflected by this White paper and reach to the LDR. A black electrical tape surrounds the LDR in the centre of the LEDs so that the tape blocks the direct light from the LEDs from reaching the photocell (LDR), thus detecting only the reflected light from the white paper. Each LED is turned ON one at a time and the intensity of light reflected back to the cadmium sulphide photocell (LDR) is measured. Thus when each colour is
reflected by a white paper and fall upon the LDR, eight different values of resistance across the LDR are obtained, as well as eight different voltage drops across the LDR is recorded through signal conditioning circuit.

**A. The Light Source using Light Emitting Diodes (LED)**

The light source circuit shown in Fig.2, is made up with LEDs and resistances. A light-emitting diode (LED) is a semiconductor light source used as indicator lamps in many devices. In early 1962 introduced as a practical electronic component LEDs emitted low-intensity red light, but modern versions are also available across the visible, ultraviolet, and infrared wavelengths, with very high brightness. A resistance of 6kΩ is connected in series with each LED. The LEDs are connected in parallel to each other. The circuit is given a 5 Volts supply.

![Figure.2. The Light Source](image)

**B. A Light Detector using Light Dependent Resistor (LDR)**

A photoresistor or light dependent resistor (LDR) is a resistor whose resistance decreases with increasing incident light intensity. An elementary voltage divider circuit as shown in Fig.3, is used to convert the resistance variation of the LDR into voltage variation. The LDR is connected with an appropriate resistance, so as to divide the reference voltage (5V) between itself and the fixed resistor (R₄). As the light intensity varies, so does the voltage across the LDR. The key idea is to record these voltage across the LDR when the object is illuminated by one of the three colours.

![Figure.3. The Light Detector Circuit](image)
A photo resistor is made of a high resistance semiconductor. The voltage across the LDR is measured by simply putting another resistor of 1kΩ in series with it. This gives a potential divider circuit. The resistance of the Light Dependent Resistor (LDR) varies according to the amount of light that falls on it. The relationship between the resistance ($R_5$) of the LDR and light intensity Lux is given by

$$R_5 = \frac{500}{\text{Lux}} \, \text{kΩ}$$

With the LDR connected to 5V supply ($V_s$) through a resistor ($R_4$) of 1kΩ, the output voltage ($V_D$) across the LDR is given by,

$$V_D = \frac{V_s \times R_5}{(R_4 + R_5)}$$

The variation of the output voltage ($V_D$) with either $R_4$ or $R_5$ is non-linear. Reworking the equation, we obtain the light intensity,

$$I \, \text{(Lux)} = \frac{2500}{V_D - 500}/R_4$$

Thus, we get eight different variations of voltage with the variation of the resistance of the LDR achieved according to different colours. So, changes in voltage drop are obtained by varying the intensity of colour reached on the LDR from the LEDs.

### III. ANALOG SIGNAL CONDITIONING CIRCUIT DESIGNED FOR THE COLOUR SENSOR

![Signal Conditioning Circuit](image)

**Figure.4. Signal Conditioning Circuit**

A signal conditioning circuit has been developed as shown in Fig.4, to convert the sensor signal into suitable form required by the controller unit. It consists of a buffer, a differential amplifier, an inverting amplifier and a zero span.
adjustment circuit. The LDR is placed as one of the resistors in the voltage divider circuit in series with the 1KΩ resistor. The LDR used here has the maximum resistance in a dark place which is near about 2MΩ. The resistivity of LDR also depends on the temperature of the surrounding environment which causes the voltage across the LDR to fluctuate and voltage drop occur across it. To avoid this voltage drop across the LDR an operational amplifier has been used as a buffer so that it can compensate the voltage loss and give a linear response in variation with colour and the intensity of illumination. The output voltage increases gradually when each LED is turned ON in a proper sequence. A linear plot of decreasing order is achieved by using the output voltage of the buffer. A differential amplifier has been used to amplify the output of the buffer and to achieve the output in an increasing order. Some output of the differential amplifier have negative values, to change these values into positive values and to amplify the overall voltage range, an inverting amplifier has been also used here. Thus, the inverting amplifier changes the negative slope into positive. Finally the output voltage of the signal conditioning circuit is limited in between 0-5 volt by using a Zero Span Adjustment circuit. These analog values of output voltages is fed to the IC ADC0804 which covert it into the digital data to be fed to the 8051 Microcontroller.

IV. OPERATION OF THE OVERALL SYSTEM

A photo resistor (LDR), made of a high resistance semiconductor, can also be referred to as a photoconductor. These, Colour sensors sense the colour of an object or a light and produce an electrical signal depending on its intensity, angle of incidence and wavelength or frequency. Therefore it can sense and differentiate between different colours and their combinations. When light of a particular colour falls on LDR, the resistance of LDR decreases. This type of LDR is called negative co-efficient LDR. There are some LDRs that works on the opposite way. Their resistance increases with increasing light intensity. This type of LDR is called positive co-efficient LDR. If the LDR is given a supply an output voltage is produced across it which depends on the intensity and wavelength of different colours of light. Fig.5. shows this relation between resistances of LDR with illumination of colour.

![Figure 5: Resistance as a function of Illumination](image)

The sensitivity of an LDR or photo detector is the relationship between the light falling on the device and the resulting output signal. The voltage across the LDR is measured by simply putting another resistor in series with the LDR. This makes us a potential divider, and the voltage across the LDR is proportional to the current. Fig.6. shows the block diagram of the overall proposed system consisting of the sensor circuit, the signal conditioning circuit, the controller unit and the Stepper Motor driven by the Stepper Motor Driver. The photo sensor designed with the help of LDR surrounded by three LEDs senses the variation of the light intensity falling on it, depending on which a variation of voltage across it is obtained. This output voltage is then manipulated by a signal conditioning circuitry and Analog to Digital Converter (ADC) Circuit in suitable form which is fed as input to the 8051 Microcontroller. The Microcontroller receives the digital data and executes the software program loaded in it to generate pulse sequence fed to the Stepper Motor Driver Circuit which causes the Stepper Motor to rotate to achieve the desired angular position of the robotic arm manipulator.
V. INTERFACING OF THE STEPPER MOTOR DRIVER WITH THE CONTROLLER UNIT

A controller unit has been used here to achieve the required angular position of Stepper motor to be used in robot arm movement in response of the colour sensed by the colour sensor. Eight different angular positions of the Stepper Motor have been achieved in anti-clockwise direction for the eight different colours. The Stepper Motor Driver IC ULN 2003 has been connected with the output of the microcontroller as shown in Fig.7. The controller unit executes the developed control software and generates the sequence of bit pattern 9, 5, A, 6 to energize the windings of the stepper motor through the driver IC ULN2003 which changes the angular position of the Stepper motor in anticlockwise direction.

VI. EXPERIMENTAL RESULTS AND DISCUSSIONS

In the proposed work the resistance across the LDR in variation with colour intensity has been plotted in Fig.8. The different resistance across the LDR has been observed whenever the illuminated light to the LDR is changed as shown in Table.1. At first all three LEDs are OFF and the LDRs resistance is near about 105 kΩ, gradually the value decreased up to 2.45 kΩ when all three LEDs are turned ON at the same time.
The experimental voltage variation across the LDR placed in the voltage divider circuit with the change in colour of LEDs as shown in Fig.9, is obtained which is almost linear. It has been observed that the voltage variations are too close to each other and the curve is decreasing with a negative slope. So a better positive slope with differentiable voltage is required.

Differential OM-AMP has been used to change the response of the sensor to an increasing slope starting from null voltage. The variation of the Output of the Differential OP AMP in the signal conditioning circuit with the Colour has been plotted in Fig.10. An increasing slope of the variation of the voltage drop across the LDR obtained from the output of the Differential OP AMP with the change in the colour combinations has been achieved. The response curve obtained is also almost linear.
The Controller unit used can recognize voltage signals in the range of 0-5Volts. Therefore the output of the Differential OP AMP is given as input to the Span Zero Adjustment Circuit which limits the output voltages between 0.95 - 4.90 volts and has a linear relationship with the change in colour. Fig.11. shows this linear response curve of the output of the span zero circuit. This output voltage of the Signal Conditioning Circuit is in the range 0-5 Volts and this is indicated in Table.1. This final output voltage is converted into its equivalent digital form by the ADC Circuit used which is given as input to the 8051 Microcontroller.
Table 1. Variation of LDR Output and Angular Position of Stepper Motor with Color

<table>
<thead>
<tr>
<th>Color No.</th>
<th>Input Light of LED</th>
<th>Resistance of LDR (KΩ)</th>
<th>Output obtained after Signal Conditioning (Volts)</th>
<th>Angular Position of Stepper Motor (Degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0</td>
<td>105</td>
<td>4.90</td>
<td>140°</td>
</tr>
<tr>
<td>2.</td>
<td>0</td>
<td>28.4</td>
<td>4.40</td>
<td>125°</td>
</tr>
<tr>
<td>3.</td>
<td>0</td>
<td>12.6</td>
<td>3.70</td>
<td>111°</td>
</tr>
<tr>
<td>4.</td>
<td>0</td>
<td>7.25</td>
<td>3.15</td>
<td>93.5°</td>
</tr>
<tr>
<td>5.</td>
<td>1</td>
<td>4.95</td>
<td>2.60</td>
<td>76°</td>
</tr>
<tr>
<td>6.</td>
<td>1</td>
<td>3.62</td>
<td>2.00</td>
<td>60°</td>
</tr>
<tr>
<td>7.</td>
<td>1</td>
<td>3.03</td>
<td>1.55</td>
<td>45°</td>
</tr>
<tr>
<td>8.</td>
<td>1</td>
<td>2.45</td>
<td>0.95</td>
<td>28°</td>
</tr>
</tbody>
</table>

Fig. 12 shows the percentage error curve of the output voltage of the span zero adjustment circuit. The percentage error from linearity in measuring the output of the Signal Conditioning Circuit lies within -2.43 to 3.33%.
The variation of the angular position of the Stepper Motor with the corresponding change in the colour of the LEDs has been indicated in Table 1 and is shown in Fig.13. For eight different colour combinations, angular position between 28° and 140° is achieved by the Stepper Motor as shown in Table 1. The response shows a linear relationship between the colour and the angular position of the Stepper Motor. The percentage error curve in Fig.14 shows that from linearity the percentage error in measuring the angular position of the Stepper Motor lies between -1.19% and 1.89%. The above system designed can be applied in pick and place operation of robot arm movement.
VI. CONCLUSIONS

In the present paper the design and development of a low cost colour sensor and its application in angular position control of a Stepper motor has been achieved. The response of the resistance of LDR in variation with colour is exponential. By using the LDR in a divider circuit a linear slope of voltage across the LDR has been achieved. Through signal conditioning the voltage of the colour sensor has been manipulated in between 0.95 - 4.90 volts. This voltage is further fed to a controller circuit followed by an Analog to Digital converter ADC circuit which gives the digital values of the voltage variation which is given as input to the 8051 Microcontroller. The controller circuit controls the angular position of the Stepper Motor in response to the various colour combinations sensed by the LDR which can be used in mechatronics and robotics applications.

VIII. REFERENCES