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Petroleum products color detecting system using RGB color sensor

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***Abstract*: -** In this project we are going to study petroleum products color detection system, which is based on colorimetry and color measurement theories. We use the RGB color sensor TCS320 as the color acquisition unit, enhanced 51 series microcontroller STC12C5A60S2 as the control unit. In order to increasing the system accuracy and reliability, we use the software processing methods such as white balance adjustment and instrument zero calibration. Experiment proof that the system has the advantages of simple hardware structure and strong anti-interference capacity.

Key words: *- TCS320, color detection, microcontroller STC12C5A60S2*

I. INTRODUCTION

With the development of colorimetry and relative theories, color recognition technology is widely used in different industries. For example, in the petrochemical industry we can preliminary analysis the colloid content by observing the color of the petroleum products, but in the lube oil there are some additives which has its own color, so, it is not authoritative to determine the high quality just by observing the color of the products. So we need to measure the color of the petroleum products carefully so that to distinguish the composition of the color. There are two methods used for color measurement, spectrophotometry and photoelectric integrating method. The spectrophotometry is a kind of indirect measurement method, it not measure the color of the object to be measured directly, but measure the light energy of the reflected or transmission light from the object indirectly, and then calculate the tristmulus values of the color form spectral characteristics analysis. The photoelectric integrating method is a kind of direct measurement method, it measure the spectrum energy of the object directly, so that to get the tristmulus values of the color of the object. In this project we are going to study a petroleum products color detection system, use the RGB color sensor for tristmulus values acquisition, then compare the data with the color values defined by CIE, so that to make sure the color of the petroleum products. The system can not only detect the color of the petroleum products, but also preliminary analysis the colloid content according to the color measurement results.

II. TRISTIMULUS VALUES MEASURING PRINCIPLE

If we want to get a new color such as C, we need a process called color matching, in which match the three primary colors (red, green, and blue) together quantificationally, the quantity of the three colors is called tristimulus values. So we can express any color C as follow:

$$C(C) \equiv R(R) + G(G) + B(B) \tag{1}$$

Here the symbol"$\equiv$"means color matching. In addition, different color also can be expressed as $\phi(\lambda)$ (called color stimulation function). It thus appease that color measurement in fact is solving the function $\phi(\lambda)$ of the object by mathematical means.

The stimulation function $\phi(\lambda)$ of transparent objects is related to both the spectral distribution $S(\lambda)$ of the lighting source and the spectral transmission factor $T(\lambda)$ of the object, it is expressed as:

$$\phi(\lambda) = S(\lambda) \cdot T(\lambda) \tag{2}$$

The stimulation function $\phi(\lambda)$ of non-transparent objects is related to both the spectral distribution $S(\lambda)$ of the lighting source and the spectral reflectance transmission factor $R(\lambda)$ of the object, it is expressed as:

$$\phi(\lambda) = S(\lambda) \cdot R(\lambda) \tag{3}$$

According to the tristimulus value formula, the relation between color stimulation function $\phi(\lambda)$ and the tristimulus values of the color is listed in below.

$$\begin{cases} X = K\int_{\lambda} \phi(\lambda)\bar{x}(\lambda)d\lambda \\ Y = K\int_{\lambda} \phi(\lambda)\bar{y}(\lambda)d\lambda \\ Z = K\int_{\lambda} \phi(\lambda)\bar{z}(\lambda)d\lambda \end{cases} \tag{4}$$

Where $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ are the spectral tristimulus values defined by CIE, can be obtained through the look-up table, K is a normalization coefficient of the lighting source or illuminate object, it is calculated according to the formula:

$$K = \frac{100}{\int_{\lambda} S(\lambda)\bar{y}(\lambda)d\lambda} \tag{5}$$

The tristimulus values X Y Z of the color under test can be calculate from the formula. Then we can determine the color of the object.

III. DESIGN OF COLOR DETECTING SYSTEM

Since the petroleum products are always liquid, according to the Beer-Lam-bert law, for the liquid color measurement, transmission method is recommended, so that to get more reliable spectral power distribution curve and then indentify the color of the liquid accurately. We adopt the transmission method in this project.

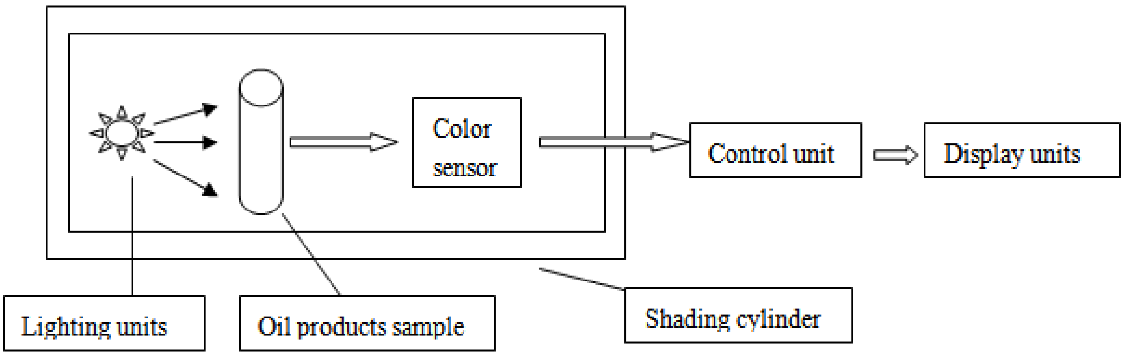

Fig1.Structure of the color detecting system

The functional modules of the system are as follow: LED lighting units, RGB color sensor units, control units and color information display units. Fig1 is the structure of the overall detecting system in block diagram.

IV. HARDWEAR DESIGN

4.1 Lighting units

The lighting source and collimating system constitute the lighting units. The lighting source is made up of six white patch type high brightness LED, which distribute uniformly on a diameter of about 3cm circumference. The collimating system adopts double cemented lens, then we place the LED lighting source at the focus of the collimating system. After the system is powered on, open the lighting source, then the collimating system converts the unparallel nouniform LED light intensity to a parallel and uniform light intensity, so that facilitate the application.

4.2 Measurement and control units

This design adopts RGB color sensor TCS230 produced by TAOS, it can convert the colorful input light to frequency signal as output, since the TCS230 chip integration with 3 kinds(red, green and blue) of color filter. TCS230 is the first RGB color sensor chip compatible with digital interface. Fig2 and fig3 are the soic package and functional block of TCS230

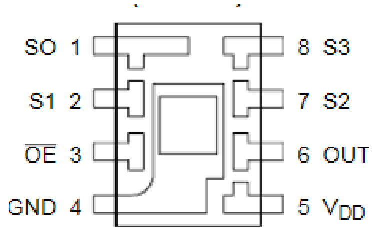

Fig2 Soic package of TCS230

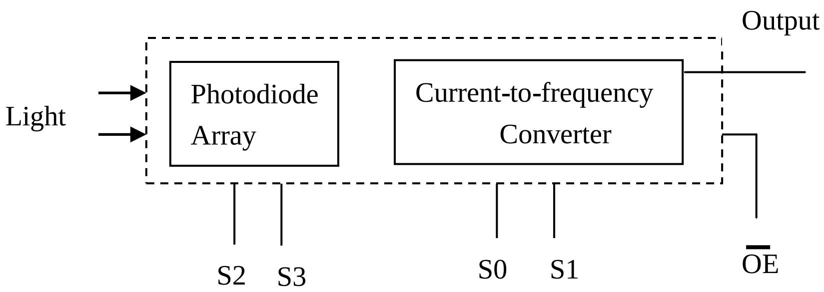

Fig3 Functional block diagram of TCS230

The microprocessor adopts industrial-grade microcontroller STC12C5A60S2. It is a new generation of 8051 single chip, compare with the traditional 8051, it has the advantages of high speed, low power consumption and strong anti-interference, its instruction code is fully compatible with traditional 8051, but faster than the traditional 8051 8`12times.

The operation mode of the filter in the color sensor is controlled by the two I/O ports P12 and P13 during the color measurement. When the sensor TCS230 color filter in a state of selecting module, it passes through only the specific primary color, but remove the other two primary colors, so that we can obtain the output frequency of the primary colors within the stipulated time. The power off mode or the value of output-scale-factor is controlled by the two I/O ports P10 and P11, since different output-scale-factor corresponding to different measurement range. The frequency output of the TCS230 is connected with the I/O port P14 in the MCU. Table 1 list the combing control signal in MCU.

Table1 Selectable options of single chip control signal

P12	P13	Photodiode type	P10	P11	Frequency scaling
0	0	red	0	0	powered off
0	1	blue	0	1	2%
1	0	Clear(no filter)	1	0	20%
1	1	green	1	1	100%

4.3 Color detection circuit design

The hardware circuit design of the system includes color sensor circuit, MCU smallest system and 12864LCD display circuit. Since the output of the TCS230 is digital signal, it is not necessary for the system to have A/D convertor, so we can simply connect the color sensor to the MCU. In the MCU smallest system, the reset circuit adopts manual reset, the crystals adopts external clock circuit. In this project we enhance the driving capability of P0 port by connecting externally 4.7 $k\Omega$ pull-up resistor RB1, since the structure of P0 port in the MCU is open-collector. In fact we can adopt inner crystals and power-on reset to simple the circuit design. The display circuit adopts the back light character type 12864 LCD, the power voltage is 5 volts, the tristimulus values are displayed on it. Fig4 is the color detection circuit of the system.

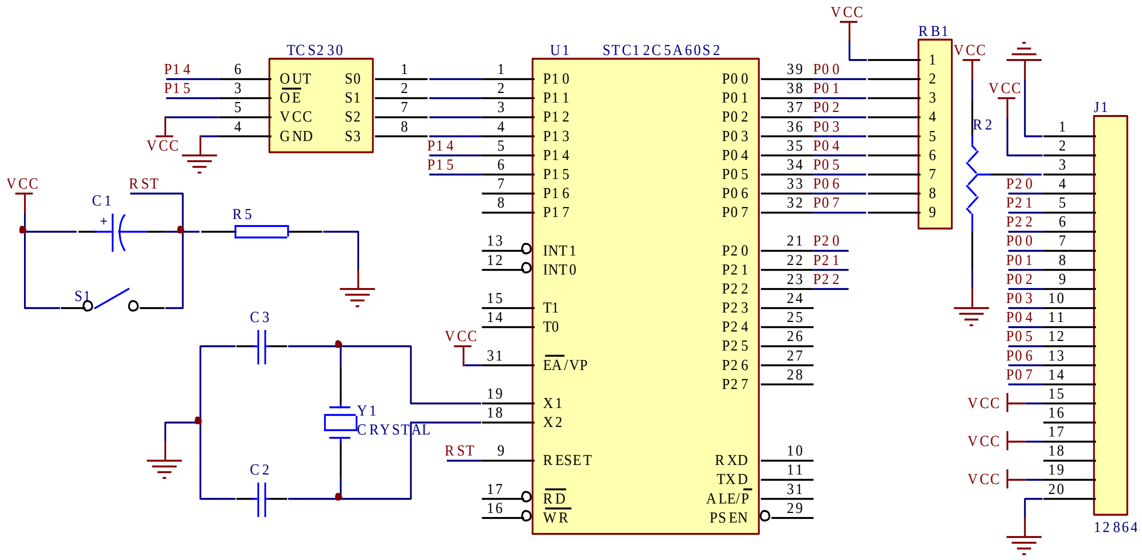

Fig4 Color detection circuit of the system

V. SOFTWARE DESIGN

White is the mixture of the three primary colors in equal proportion according to the color matching theory. The experiments proved that the proportion of three primary colors is not equal for white color products detected by TCS230, since the discordance of the sensor sensitive to the three primary colors. It is necessary to do white balance adjustment before color measuring, so that the three primary colors in equal proportion when measure white color used TCS230.

After the system is powered on, first adjust the white balance, and then execute the oil color tristimulus values measurement task. The products color tristimulus values measurement process is as follow: gate on the three color filter of TCS230 in order, using the timer T0 of microcomputer time the same interval of each channel respectively, then using the timer T1 count the number of the impulse in each channel, so the tristimulus values

R, G, B can be calculated by the number of impulses in each channel. The program flow chart of the system is as Fig5.

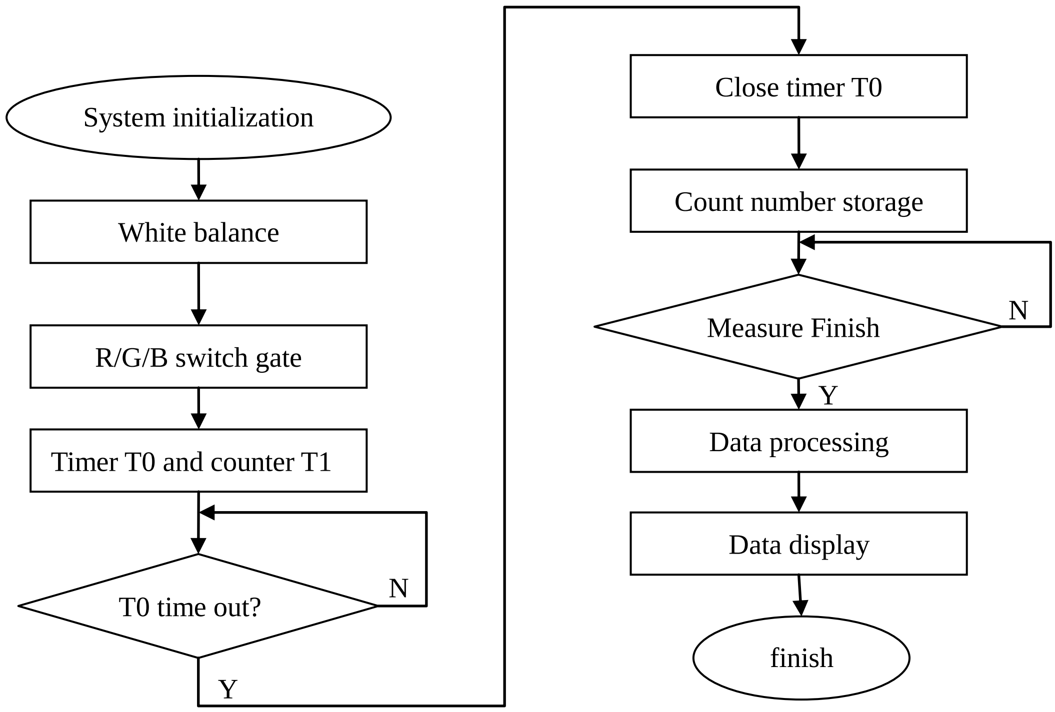

Fig5 Flow chart of the system

VI. EXPERIMENTAL PROCESS ANALYSIS

Before color measuring, we need calibrate the device so that to reduce the system error and improve the measuring accuracy. The calibration process was done in a dark room that enclosed totally. The tristimulus values at zero point are R0 G0 B0 which measured by TCS230 in the dark room, then during the following products color detection process, we got the color tristimulus values by subtracting the T0 G0 B0 from values measured after white balance process R G B. The tristimulus values of 7 kinds of lubricating oil was measured by the system, and the results as table 2.The measuring scale is 0-255, the results of the measurement is present by positive number, and the values at zero point is R0 G0 B0.

Table2 Selectable options of single chip control signal

Oil sample	R	G	B
1	205	130	65
2	241	230	145
3	255	220	170
4	240	165	96
5	212	85	30
6	160	70	45
7	140	100	20

We found from the experimental that the color of the lubricate oil without additive is from faint yellow to dark brown, and the pectin content in the oil become higher, the color of the oil become darker. From table2 we found that the system we designed can be used for detecting the color of different petroleum products, and have higher accuracy. Compare the measured values with the specified values of different colors cited by CIE, we can get the color of the oil product determinately.

VII. CONCLUSION

The petroleum products color detection system based on microcomputer STC12C5A60S2 and color sensor TCS230 has the advantages of simple construction and ease of handling. Experimental results show that the system has good effects on the oil products color detection, and measuring results are accurate and reliable. The application and generalization of the system may have certain practical value on the analysis of petroleum products.

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