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Design and Development of Low Cost Portable Opacity Measurement System using Advance Embedded Controller

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Abstract: The low cost portable opacity measurement system is developed to overcome the limitation inherent in fairly accurate method using Portable Opacity Measurement System. Security system finds that tinted glass in vehicles has been major source of concern for women's security as well as criminal activities. To measure the transparency of glass film opacity of vehicles windshields, traffic police and cops should equipped with precise instrument so as the transparency of glass should be within permissible limit as per traffic regulations. The proposed work describes the application of a light intensity measurement to monitor light properties of semi transparent sheets of various materials and presents a novel technique to measure thickness and opacity of tinted glass or acrylic sheet.

Keywords: POMS, Design, Opacity, Microcontroller, Embedded system.

I. INTRODUCTION

Partially Black painted glass in vehicles has been a major source of concern for women's security as well as criminal activities. Such car windows have facilitated criminals especially in cases of rape and murder [1]. Some kind of strict *precautions that can* greatly *reduce* the chance of criminal hazards. Traffic police now intends to intensify the drive against use of coloured glass in motor vehicle. As per " Rules of Road Regulation, 1989 framed by the central government of India under Section 118 sub rule of the Motor Vehicles Act", the acceptable limit, should be at least 70% transparency in the film on the front and back windows while 50% visibility is required on the side windows[2]. Vehicle beyond the visual light transmission (VLT) limit that blocks light by more than 30% for the front / rear windshields and 50% for the side windows would be considered as criminal offence and hence punishable. There has been a traffic police drive against tinted car windows since last year. However, there has been a strict action taken this year, with only 9,279 such prosecutions till end of the year. Last year, for the same period, there had been as many as 30,582 prosecutions. Cops claim that better compliance has resulted in lower prosecutions. Possibility of approximate measurement and wrong judgment of glass film opacity cannot be denied, that lead the traffic control police to impose improper rules, regulations, Act and wrong penalties can be marked on the vehicle owner's results in harassment and mental frustrations. Traffic security hence more concerns of measurement and monitoring glass opacity of tinted glass that needs to the development of a portable opacity measurement system in an innovative way. From a clinical and occupational viewpoint also, the classification of X-Rays films is primary importance [3]. The proposed work describes the application of a light intensity measurement to monitor light properties of transparent sheets of various materials [4]. These properties include thickness, calliper, opacity, moisture and lightness.

The usual method of determining the opacity quality of an entire sheet was to carry out statistical computation on a step by step basis of sheet properties in direction, length, and width. On a profile-by-profile basis, it can be somewhat difficult to determine whether the entire sheet is within the desirable opacity grade specifications or not, or whether the specification is only out of limits at certain sets. This difficulty can be overcome by use of optical sensing technology. First film samples were cut into rectangles pieces and placed inside a proposed transducer. A phototransistor can be used to monitor [5] the entire sheet for various light properties. This means less time will be required for statistical calculations. Feedback from analysing the opacity would enable to identify possible problems associated with the transparent sheet machine controls. In addition, trimming information can be derived from the measurement if any undesirable streaks are present in the sheet. The light detector was developed as a sensing tool for the production machine, as part of a Portable Opacity Measurement system (POMS).

A literal definition of opacity is the degree to which the transmission of light is reduced or the degree to which the visibility of a background as viewed through the diameter of a cloud is reduced. In simpler terms, opacity is the obscuring power of the film density, expressed in percentage.

$$\text{Percent Opacity} = \frac{1 - \text{I}}{(\text{I}_0)} \times 100$$

The relationships between light transmittance and opacity [6] are presented in given equation. In physical terms, opacity is dependent upon transmittance (I/I0) through the denser medium, where I0 is the incident light flux and I is the light flux leaving the film medium along the same light path. Some authors claimed that opacity decreases with increasing wavelength [7], this hypothesis is good agreement to develop the design. Accurate detection of

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light opacity is used in the design of the system and development of the method presented in this paper. The measurement of percentage opacity of x-ray film samples is described and demonstrated. After describing the specifics of the complete system architecture in Section-II, the other hardware and software components of the designed system are described in Section-III. The sampling and experimental setup of absolute measurement method in Section IV is followed by the calibration of measurement results for error analysis in Section V. The achievements of results are demonstrated in Section VI for common plastic film. Finally, Section VII contains the discussion of the results with conclusions about the usefulness of the proposed method for opacity measurement.

II. SYSTEM ARCHITECTURE

An attempt is made to describe hardware design of portable opacity detection and measuring equipment. This enables the meter to detect opacity percentage and continue to measure reliably. The heart of the meter is an **A**dvanced **V**irtual **R**ISC (AVR) AT89C51 microcontroller. All measurements are carried out in the digital domain and measurement results of designed transducer are available in the form of light intensity amplitude that could be transformed into plain-text values, accessible over the Universal Synchronous Asynchronous Receiver Transmitter (USART) interface. This enables cost-efficient applications based on LCD (Liquid Crystal display). Alternatively, the design well suited for more computerized applications with features such as Serial communication Interface and other General Purpose Interface Bus (GPIB) Devices. With careful PCB design and following the guidelines given in this document the accuracy can be further increased.

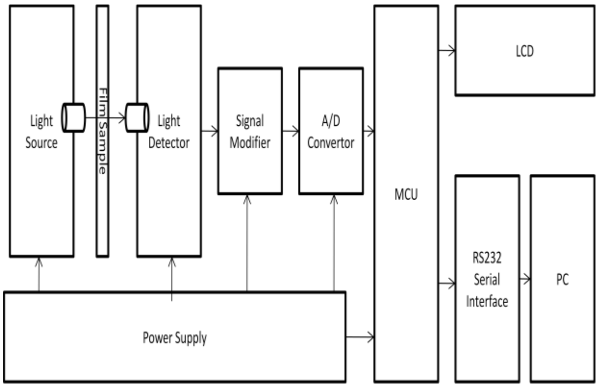

Fig. 1. System Block Diagram

The microcontroller section includes the AVR Atmel89C51 and the clock source. It can be configured to run from internal RC clock, as described in the data sheet. Using the internal clock generator removes the necessity for an external crystal and lowers the overall price of the meter. The drawback of internal oscillator (similar to any RC and LC oscillator) is sensitive to variations in temperature. This means the frequency changes with change in ambient temperature and hence results will change accordingly. In addition, the bit error rate of serial communication will increase if the system clock is not stable enough. Also this section includes A/D converter along with all analog input and output digital circuitry. Insufficient memory with the Atmel89C51 leads the design to migrate into any other AVR processors.

Alternative design ideas include:

- Remove Opacity Detection logic and turn the design into a standard meter. Firmware should then fit into 4kB and the microcontroller can be replaced by an Atmel89C51
- Add functions such as serial communication with desktop, Alarm Buzzer, Light Indication, demand recording or multiple tariffs. Upgrade to Atmel89C52, for example, if the firmware exceeds 4kB.
- Add integrated LCD support simply by migrating to higher version of AVR Processors.

III. PROGRAMMING INTERFACE

The programming interface is required for programming the microcontroller and for calibrating the meter. Using the Serial Programming Interface (SPI) of the AVR, we can access both Flash and EEPROM via the same connector. Complete software programming and calibration can be carried out at any time.

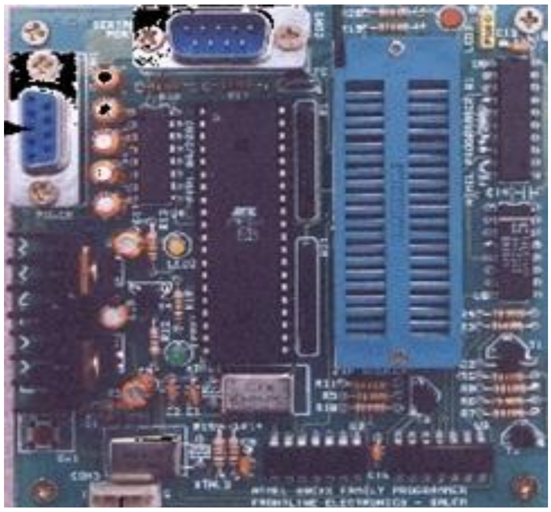

Fig. 2. Topview Programmer Used in Application

The application uses the Universal Synchronous Asynchronous Receiver Transmitter (USART) interface of the AVR to send measurement data. Any GUI (Graphic User Interface) software can be used for sending commands to the meter and for receiving measurement data. Measurement results, once calibrated, meter will be ready to give results in terms of percentage Opacity.

The proposed meter contain a level converter RS-232 interface and the signals can therefore be directly connected to the USB (Universal Serial Bus) port of a computer. The RS-232 auxiliary connector on Topview Programmer (Frontline Electronics make) also contains a voltage level converter and can therefore be act as a buffer between the meter and the computer.

IV. SAMPLING

The Analog-to-Digital Converter (ADC) is set to operate in Free Running Mode, which means a new conversion will initiate instantly after the conversion at an hands completes. At the end of a conversion, the ADC raises a hardware interrupt signal and the Microcontroller starts executing the Interrupt handling sub-routine. This sub-routine program reads, processes, and stores the sampled data at predefined memory location and then returns back to the main program for further execution. The main program is mostly redundant state; it is triggered only when a sufficient amount of data has been build-up for the end-of-cycle calculations to start. Once started, the ISR may still continue to interrupt the main program, even when it is busy calculating.

V. HARDWARE SET-UP

For operating independently, the meter is simply powered to the 9.0V DC Battery Supply and put the Input plastic Film sample inside the slot of designed sensor as illustrated in the schematic. The meter automatically starts to measure Opacity and show the output result on the LCD display. Note that the Instrument needs to be calibrated before reliable measurement. For programming, calibration and testing purposes the meter needs to be temporarily connected to external hardware, such as a computer or a microcontroller. The external hardware writes the firmware into the FLASH memory of AT89C51 Microcontroller. It then assesses the accuracy of the meter and writes calibration data into the EEPROM of the MCU. The meter is prepared for stand-alone run mode after successful programming and calibration.

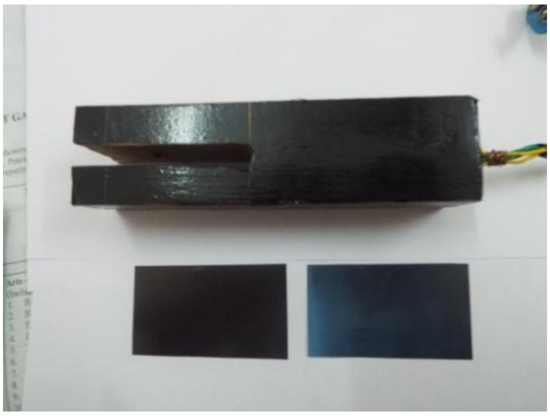

Fig. 3. Opacity Transducer with Film Samples

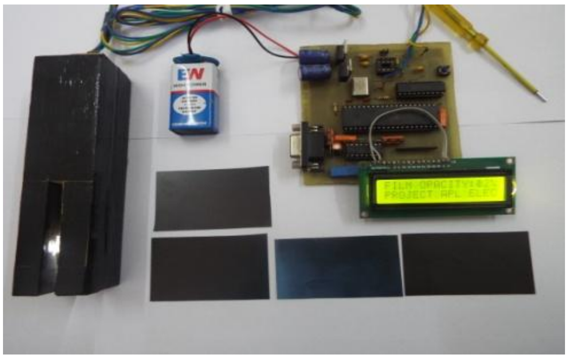

Fig. 4. Complete hardware Setup for experiment

VI. CALIBRATION

Two meters should not be alike and no individual variations are to be expected. Typical tolerance figures for components used in the meter are 2%, which means the assembled meter has an inherent error of the same magnitude. Hence, each measuring device must be pre-calibrated before truthful measurement result can be obtained. Rather than populating the meter with trimming resistors and manual calibration, the procedure is readily carried out in the digital domain.

Calibration coefficients are first calculated for each A/D digital output individually, then stored in on-chip EEPROM and later retrieved during firmware initialization. Digital calibration is accurate and efficient, it is quick to perform, requires little or no manual involvement, and does not change with time. In addition, calibration data is safely stored in the internal EEPROM

The EEPROM layout of 8-bit calibration coefficients is shown in the table below.

TABLE I: CALIBRATION COEFFICIENT LAYOUT

Hexadecimal(H)	Opacity in Percentage (%)
00H-0FH	0-6 %
10H-1FH	7-13 %
20H-2FH	14-20 %
30H-3FH	21-26 %
40H-4FH	27-33 %
50H-5FH	34-39 %
60H-6FH	40-46 %
70H-7FH	47-53 %
80H-8FH	54-59 %
90H-9FH	60-65 %
A0H-AFH	66-72 %
B0H-BFH	73-78 %
C0H-CFH	79-84 %
D0H-DFH	85-91 %
E0H-EFH	92-97 %
F0H-FFH	98-100 %

The calibration coefficients are calculated according to further scheme. The transducer output should be in the range of 0-5 V. Depending on the input range of opacity percentage value for transducer, a conversion factor is determined. If a transducer is capable of measuring opacity parameter within the input range X1 and X2 and provides 0-5 V signal at output then calibration factor is

$$1\ \text{V} = \frac{X_2 - X_1}{5}\ \text{unit}$$

If we are converting this signal to digital through an 8-bit ADC in unipolar mode then

$$5\ \text{V} = 255 \qquad \text{and} \qquad 0\ \text{V} = 0$$

i.e.

$$1\ \text{V} = \frac{255}{5}$$

Thus calibration factor is

$$\text{ADC output}\ \frac{255}{5} = \frac{X_2 - X_1}{5}$$

$$\text{ADC output}\ 1 = \frac{X_2 - X_1}{255}$$

Conversion factor is therefore

$$= \frac{(X_2 - X_1)}{255}$$

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The conversion of ADC output to equivalent Opacity percentage value, therefore involves simple multiplication by a this factor.

If measuring device is planned to indicate the opacity in the range varying from X1 = 0 % to X2 = 100 % and ADC output ranging from 00H (0d) to FFH (255d) then

$$\text{converstion Factor will be } \frac{100-0}{255}$$
$$= 0.39\ \%$$

For ADC Output 0FH the Equivalent Opacity in Percentage is, Decimal equivalent of ADC output multiplied by Conversion Factor. i.e.

$$15 \times 0.39 = 5.45$$
$$= 6\%\ \text{Approx.}$$

Similarly for ADC Output FFH the equivalent Opacity Percentage is

$$255 \times 0.39 = 99.45$$
$$= 100\%\ \text{Approx.}$$

The designed device based on the precept of measuring light absorption by the film sample, compared to a scale of 0% preoccupation (adjusted by keeping light source ON and no film sample in place) and 100% absorption (calibrated by keeping light source OFF and no film sample in place). The light source is line-voltage powered, and produces full-spectrum detectable white light, which is not percolated; the light passes through the sample with the light source on one side and the light signal detector element on the other side of the sample. It is not a reflective-type system, nor does it use black/white reflectance plates for calibration.

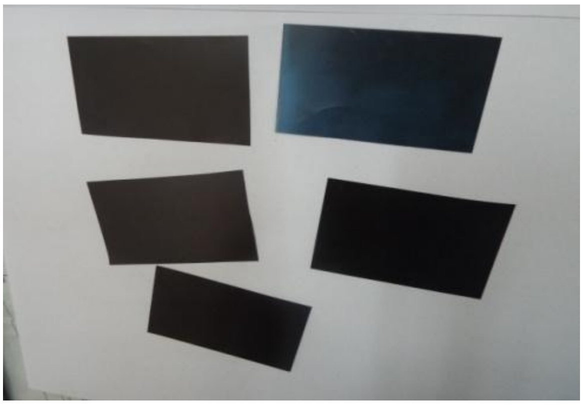

Fig. 5. Input Plastic Films Samples of different Opacity.

Fig. 6. LCD Displaying Opacity Parameter 1

Fig. 7. LCD Displaying Opacity Parameter 2

Fig. 8. LCD Displaying Opacity Parameter 3

Fig. 9. LCD Displaying Opacity Parameter 4

VII. CONCLUSION

The Proposed system has been developed as a cost-efficient option for Light Transparency and Opacity measuring. Recorded results have been reported. Several experiments were performed to obtain the test results. These experiments provided valuable opacity model tests. Comprehensive results require more experiments. Yet they are probably best regarded as proof-of-principle experiments that establish platforms for further investigations. The Opacity Meter is designed to operate as an opacity control device as a relative measurement device. It was originally made for the measurement of opacity of extruded plastic film and plastic sheet, but it does perform well for the measurement of opacity in certain other applications.

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BIOGRAPHY

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