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Design and Development of a Relative Humidity and Room Temperature Measurement System with On Line Data Logging Feature for Monitoring the Fermentation Room of Tea Factory

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Abstract: The design and development of a Relative Humidity (RH) and Room Temperature (RT) monitoring system with on line data logging feature for monitoring fermentation room of a tea factory is presented in this paper. A capacitive RH sensor with on chip signal conditioner is taken as RH sensor and a temperature to digital converter (TDC) is used for ambient temperature monitoring. An 8051 core microcontroller is the heart of the whole system which reads the digital equivalent of RH data with the help of a 12-bit Analog to Digital (A/D) converter and synchronize TDC to get the ambient temperature. The online data logging is achieved with the help of RS-232C communication. Field performance is also studied by installing it in the fermentation room of a tea factory.

Keywords: Relative humidity, Temperature to digital converter, Fermentation, Microcontroller.

1. Introduction

Tea processing basically starts with the plucking of young green leaves from the tea bush and allowing them to wither in withering troughs. The withered leaves then go to the rolling machine where the limp withered leaves are pressed between two rollers rotating in a particular fashion. This produces the particular shape of the leaves and also some breaking of the leaf cells. In the orthodox method the leaves after rolling go to the fermentation room. For CTC (Crush Tear and Curl) tea, rolled tea leaves are further cut into finer grains before being sent to the fermentation room. Proper fermentation produces a copper red color to the rolled or crushed tea leaves. Once end point is reached, the fermentation must be stopped. This is done by drying the fermented tea in drying chambers. The dried and finished tea is then checked for removing any foreign matter and finally weighed and packed, ready for dispatch to the auction centre.

The properly withered and rolled or cut tea leaves are spread in clean floor for fermenting. Exposure to air produces a copper red colour and a fragrant aroma. These changes are known as fermentation of tea. During fermentation of tea leaf, oxidation brings about chemical changes which largely determine the flavour, strength and colour of the liquor.

Fermentation process is best attained at temperature of about 21 ^{0}C to 30 ^{0}C. The temperature depends on the thickness of spreading. The thickness varies from 1.5 inches to 4 inches. Fermentation time varies from 1½ hour to 4½ hour depending upon the degree of wither, the rolling method used and the climatic conditions prevailing. The humidity of the fermentation room plays an important role in proper fermentation. The time of fermentation is also dependent on this parameter. Ventilation combined with water sprinkler is used for maintaining the humidity. At present these decisions are made on the basis of hygrometric difference only. The record of the conditions of the fermentation room, on the other hand, is essential for offline analysis also. So an instrument with on line central monitoring and data logging feature for humidity and room temperature for the fermenting room is expected to be helpful.

High precision RH measurement system is an emerging demand for many fields. Refrigeration, HVAC (Heating, Ventilation and Air Conditioning) equipment, medical equipment and atmospheric study are also few members of the domain of RH measurement [1, 2, 4, 9]. The predicted mean vote (PMV), a well recognized human thermal comfort index depends on RH, air temperature, mean air speed, mean radiant temperature, clothing insulation and activity level [7]. In most of the cases RH measurement with data logging capability for offline analysis are also required.

Widely used electrical humidity sensors are either capacitive or resistive type [4, 12, 15]. They require stable ac excitation with zero dc bias to prevent polarization [12]. Conditioning hardware with the functionalities like rectification, filtering, and linearization are required for them. This extra hardware introduces error due to the component tolerances and noises due to RF and EM interferences. The temperature drift of this conditioning circuit is a major concern over accuracy and precision [3, 8, 9]. Voltage output humidity sensors reduce these problems to a large extent. Voltage output humidity sensors are basically capacitive or resistive humidity sensor with on chip signal conditioning [11]. It is best suited for industrial application as it comes with factory calibration. Temperature compensation is one of the crucial steps for online RH measurement. It can be done either by adding temperature sensor and analog computation or by using digital temperature sensor and embedded processor.

There are several methods of calibration of humidity sensors like two pressure humidity generator, divided flow humidity generator and fixed point humidity system [4, 17]. Some of the fundamental standards for humidity calibrations are Chilled mirror hygrometer, Electrolytic hygrometer, low cost Dry/ Wet Bulb Psychrometer [10, 16-18].

2. System Architecture

The block diagram of the RH measurement system is shown in Fig. 1.

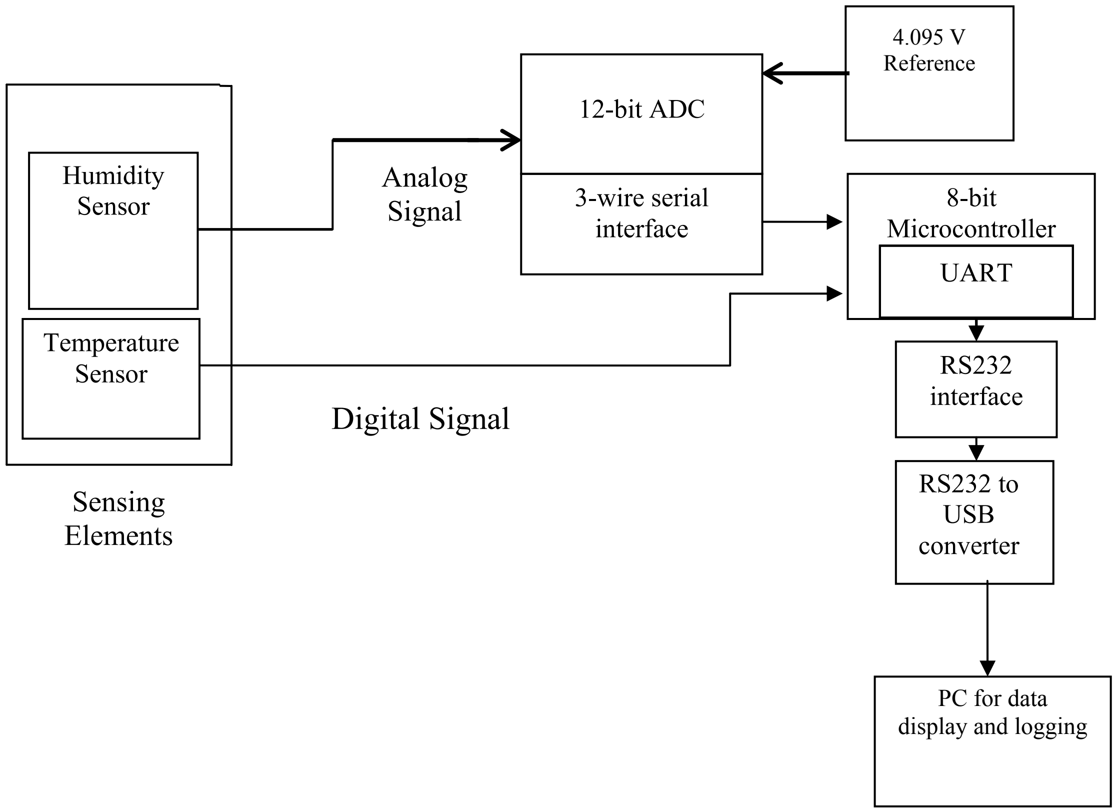

Fig. 1. Block Diagram of the RH Measurement System.

2.1. Sensing Elements

For humidity sensing, low power (200 μA at 5 V) RH to voltage converter is used [10]. It is basically a capacitive type sensing element with on chip integrated signal conditioning [5]. The sensing element is resistant to most application hazards such as wetting, dust, dirt, oils and common environmental chemicals due to its multilayer construction. The output voltage (V_{OUT}) and RH is related by the following equation typically at 25 ^{0}C [10]:

$$RH = \left(\frac{V_{OUT} \times 161.29}{V_{SUPPLY}} - 25.81 \right) \% \tag{1}$$

The true RH requires temperature correction given by the following equation [10]:

$$TrueRH = \frac{463}{(488.24 - \theta)} \times RH \ \% \ , \tag{2}$$

where “θ” is the ambient temperature in degree Celsius.

Sensing of ambient temperature is achieved by a Temperature to Digital Converter (TDC) [13]. This Serial Synchronous Interface (SSI) compatible temperature sensor requires no external component for conditioning. Digital data corresponding to the temperature can be read directly.

The RH sensor and TDC are assembled close to each other to minimize the temperature gradient between them and exposed to ambient environment.

2.2. Sensor Interface

The analog voltage output of the RH sensor is digitized by a 12-bit A/D converter with serial interface [12]. This serial A/D converter operates with no missing code, low power consumption (typically 250 micro ampere) and occupies less board space (8 pin PDIP). The reference voltage is applied from a highly stable reference with very low temperature co-efficient (10 ppm/^{0}C), excellent long term stability (10 ppm/1000 hour), low noise and excellent line and load regulations. It works from input voltage 4.5 V to 9 V [14]. The functioning of the A/D converter is controlled by an 8051 core microcontroller 89S52 (Atmel). The A/D converter is interfaced with the microcontroller using Serial Synchronous Interface (SSI). The TDC is directly interfaced with the microcontroller in SPI mode to read the ambient temperature [3]. The firmware for calculating RH using equation-1 and temperature correction using equation-2 is embedded in the flash ROM of the microcontroller. True RH is displayed in the 16X2 line character liquid crystal display (LCD) and also sent to a PC via RS232C for data display and data logging. Port 2 of the microcontroller generates required control for the LCD. Port 0 is used for data to the LCD.

2.3. Firmware

The firmware developed for this purpose serves the following task:
(i) Initialize A/D converter, LCD, UART
(ii) Read A/D converter and TDC
(iii) Calculate RH using equation-1
(iv) Calculate True RH using equation-2
(v) Send the result to LCD and to PC via RS232

3. Testing Method of the Device

The reading of the system is compared with Dry/ Wet Bulb Psychrometer in the range of 54 % to 86 % R.H., as it is a fundamental standard [5]. The system was tested in different ambient condition at different time. The error compared with the RH from dry and wet bulb is shown in Fig. 2.

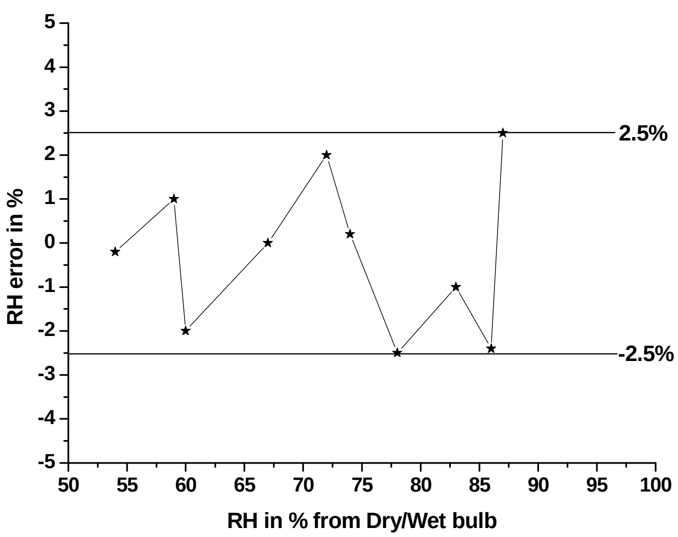

Fig. 2. Error Curve.

It is found that ± 2.5 % RH error is shown by the system in the range 54 % to 86 % RH.

A plot of data taken by the system for 12 hour at one hour interval is shown in the Fig. 3. A corresponding curve representing RH measured by Dry/Wet bulb method is also shown on the same plot. The maximum error is found to be 3 %.

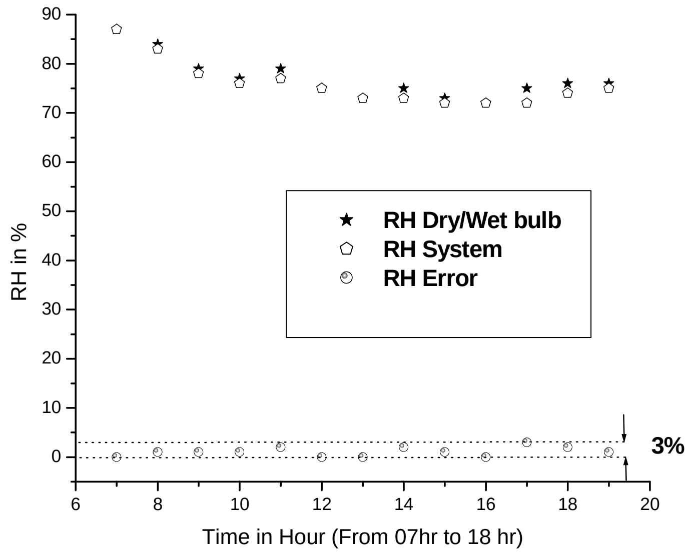

Fig. 3. Plot of data taken by the system for 12 hour at one-hour interval.

4. Field Trial

The system has been installed for testing at Sonapur Tea Factory, Sonapur, Kamrup, Assam (India). In tea processing tea leaves are fermented after withering and cutting. The RH and room temperature of the fermentation room are key parameters that determine proper fermentation, which ultimately affects the quality of tea. The system developed is installed in the fermentation room and used to monitor and store the RH and room temperature data. The screenshot of the graphic user interface (GUI) for data logging and monitoring is shown in Fig. 4. It shows the variation of RH for three hours in a particular day. The system is being run continuously during factory operation and the performance is found to be of satisfactory in the industrial environment.

A file "humidity.dat" is generated to store the data in the format shown in Table 1. The data shown in the table is a part of data file taken on 10th July, 2009.

Table 1. Sample data with data format of the humidity.dat file.

RH_comp (%)	RH_uncomp %)	RT (^{0}C)	Time (hh:mm:ss)
86.3	85.6	28.56	09:41:16
86.3	85.7	28.56	09:41:18
86.0	85.4	28.56	09:41:21
86.4	85.8	28.56	09:41:23
86.3	85.6	28.56	09:41:25
86.3	85.7	28.56	09:41:27
86.0	85.4	28.62	09:41:29
86.3	85.6	28.56	09:41:32

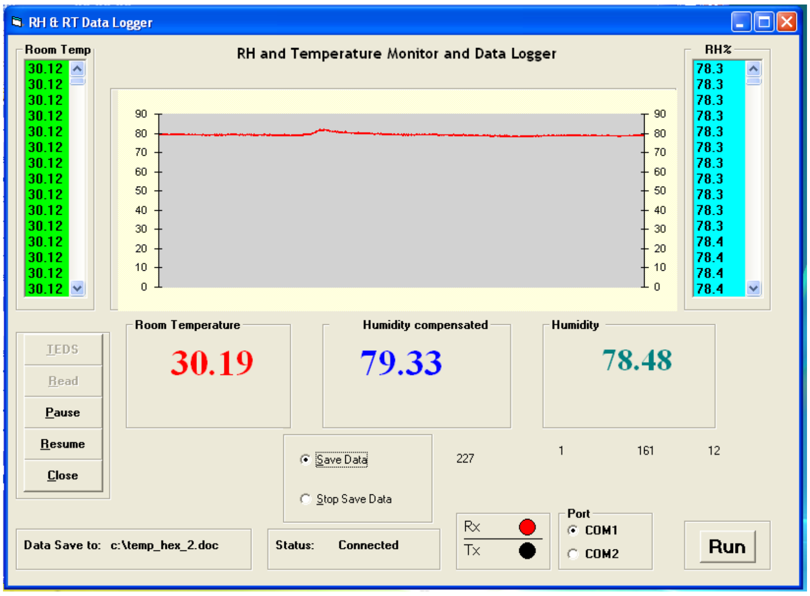

Fig. 4. Screen shot of the GUI.

Typical offline plot of RH and room temperature of the fermentation room for two days is shown in Fig. 5.

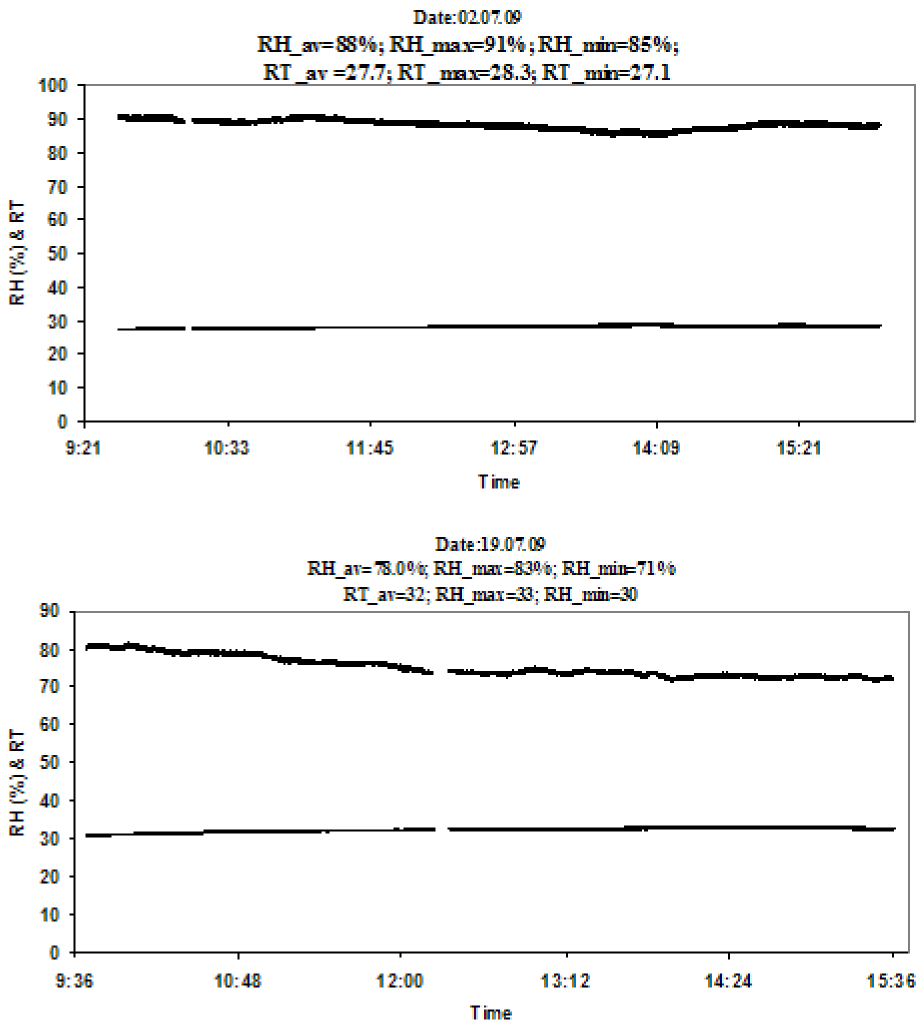

Fig. 5. Offline plot of RH and RT variation in the fermenting room for two days.

A plot of variation of average RH in the fermentation room during 6/8/09 to 9/21/09 is shown in Fig. 6. The RH_system represents the RH measured by the system. The RH_factory is the RH corresponding to hygrometric difference taken by the factory supervisor. The RH_difference is the difference of these two i.e. RH_difference= RH_factory - RH_system.

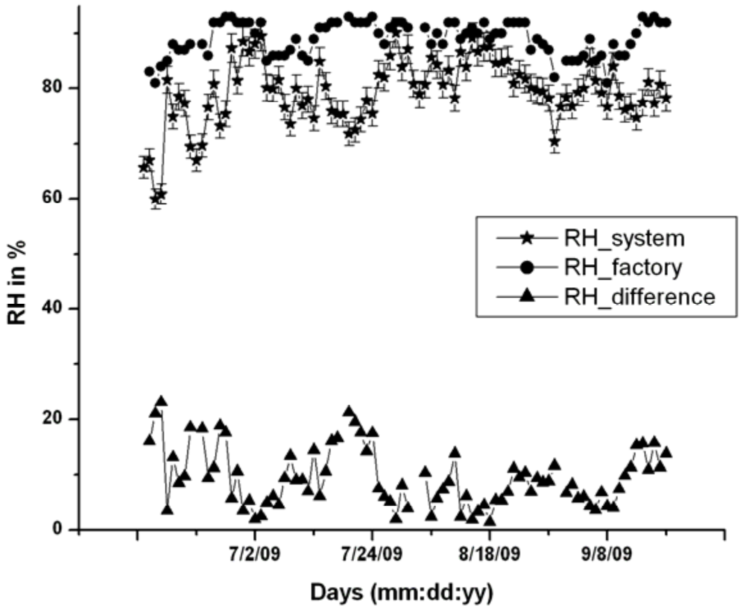

Fig. 6. Average RH variation in the Fermentation room during 6/8/09 to 9/21/09.

On average RH in the fermentation room is found to vary from 90 % to 60 % during this period. The RH corresponding to hygrometric difference taken by the factory supervisor is found to be higher than the RH measured by the system. This difference in some certain occasion found to be more than 20 %.

5. Conclusion

A RH sensor with data logging is successfully developed. Since the sensor output is connected directly to the A/D converter, there is no need of trimming for adjustment of analog output. This, together with the stable reference reduces the error and noise, which may otherwise be large due to necessary trimming. The sensor comes with factory calibration data. Since TDC is used for ambient temperature this also requires no conditioning circuit. Hence, the errors due to this are predictable. Due to these features the system requires no on site calibration. Moreover, the system is capable of independent ambient temperature and RH measurement. As the firmware corrects the RH with temperature on line it can be used as a temperature compensated RH measurement system provided RH sensor and TDC are installed near to each other.

In brief the system has the following features:

i. Relative humidity measurement with online temperature correction
ii. Room temperature monitoring
iii. Local LCD display
iv. System is interfaced with PC
v. Continuous data monitoring and data logging.
vi. Easy Firmware modification using In System Programming to support new sensor and for calibration modification.

The readings are compared with standard Dry/Wet Bulb Psychrometer and from the error curve it is found that the maximum variation of error is ±2.5 %. The maximum error is found to be ±3 % in a continuous run for 12 hours.

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