Pak. J. Agri. Sci., Vol. 45(1), 2008

AN EFFICIENT PORTABLE AND FAST RESPONSE DIGITAL HUMIDITY METER FOR USE IN THE PRESERVATION OF AGRICULTURAL FOOD PRODUCTS

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Humidity is one of the most important factors which must be monitored precisely for the preservation of food products. A digital humidity meter (hygrometer) has been designed and fabricated by employing a capacitive sensor. The performance of the digital hygrometer has been studied by comparing its relative humidity readings with a standard Thermo-hygrometer model HD-600 (Japan) which is microcomputer based and utilizes a polymer humidity sensor. Statistical analysis was performed to compare the fabricated and the standard hygrometers. The T test was performed and the value was found to be 1.6875. The standard deviation of the difference of paired values was 2.212. The performance of fabricated digital hygrometer as compared to the standard hygrometer was found to lie within 95% confidence interval. The hygrometer was found to be suitable for measuring the relative humidity. Its easy operation, capability to show direct measurement in short time and low power consumption make it best replacement of the costly humidity meters which are currently being used in the agricultural products preservation. This hygrometer can be used in the food industry, particularly in the cold storages where certain humidity levels are to be monitored. It can be used very effectively to monitor the humidity levels in green houses. This device can also be used effectively in paper manufacturing plants.
Key words: Humidity, Hygrometer, relative humidity, food preservation, humidity in cold storages.

INTRODUCTION

Humidity is one of the most important environmental conditions. Humidity is the amount of water vapor in the air. The term "humidity" is usually taken in daily language to refer to relative humidity. Relative humidity is defined as the amount of water vapor in a sample of air compared to the maximum amount of water vapor the air can hold at any specific temperature in a form of 0 to 100% Our atmosphere always contains a certain amount of water vapor. Humidity is very important factor in the preservation of materials, particularly in the storage of food products. When humidity exceeds 50% the level of bacteria, viruses, and dust miles increases in agricultural goods. Relative humidity is the ratio of the quantity of water vapor actually present in any volume of air to the quantity of water vapor required to saturate the same volume of air at same temperature (Cao and Huang, 2001). Hygrometer is a device for determining the relative humidity of the atmosphere. There are many types of hygrometer such as chemical hygrometer, Regnault hygrometer, Wet and dry bulb hygrometer etc. (Jachowicz, 1992).

Fabrication of a fast response reliable hygrometer has been an important area of research due to its applications in various fields. Particularly, the food preservation industries need to monitor the humidity levels. The storage of agricultural products depends on the humidity levels of the atmosphere. Keeping in view its importance, several studies have been conducted to develop an easy to use humidity meter. It should be calibrated from time to time during usage with agriculture products. It can be used in cement and wood industry for quality verification, Shibata *et al.* (1995) developed a digital hygrometer using a relative humidity sensor. The sensor was of a polyimide film spin-coated onto a Si substrate. Quercia *et al.* (2001) fabricated a new gas sensor device based on a porous silicon membrane. The sensible membrane had been bonded to a 1 cm^2 Al_2O_3 substrate, where electrical contacts had been previously deposited by vacuum evaporation. Kalkan *et al.* (2004) was developed a novel ionic-type humidity sensor based on a plasma-deposited nanophase Si thin film. Jiménez and Angulo (2005) discussed the use of PIC microcontroller (MCU) in measuring relative humidity. MCU measured the period of the input signal and which it converted into a digital relative-humidity reading. Islam *et al.* (2006) had found that the porous silicon (PS) was a potential candidate for developing a low cost smart relative humidity sensor, but its main limitation was that the response was a nonlinear function of humidity, suffering from hysteresis and drift due to aging. Li *et al.* (2006) introduced a digital hygrometer that was made up of MSP430F449 MCU and humidity transducer HIH-3610. Su and Huang (2007) fabricated resistive-type humidity sensors through in situ photopolymerization of pure polypyrrole (PPy) and TiO_2 nanoparticles/ polypyrrole (TiO_2 NPs/PPy) composite thin films on an alumina substrate.

In our work we have fabricated a digital hygrometer using locally available components. It consists of integrated circuits, resistors, capacitors, humidity sensor and seven segments LED displays. This hygrometer may be used for storage of edibles and other agricultural products like tobacco and dried crops (Qiu *et al.* 2006, Sanchez and Castanera, 2007).

MATERIALS AND METHODS

We used a capacitor based humidity sensor (Matko and Donlagic, 1996). The humidity sensor is a capacitor formed from a dime sized piece of plastic film that is coated on both sides with a thin layer of gold. Because the dielectric constant of that film varies with changes in relative humidity and so does the sensor's capacitance. On each side of film, gold functions as one plate of capacitor. The sensor had a humidity range of 10-90%, temperature range 0-85 degree centigrade. The capacitance (at 25 degrees centigrade, 43% relative humidity and at 100 kHz. Frequency) was 122 pF, 15%. Maximum voltage is 15 volts.

Relative humidity is measured with an oscillator whose frequency is varied in response to change in the sensor's capacitance. Two oscillators are used in this circuit to measure the difference between their outputs. A detector circuit transforms these pulses into direct voltage, the level of which is a measure of the humidity of air. This direct voltage is applied to an analogue to digital converter, the output of which is applied to a BCD to seven segment decoder/driver circuit which displays the relative humidity.

The components used in the fabrication of hygrometer are listed below:

Integrated circuits: NE 555: Timer, 4001B: CMOS dual input NOR gate: CA3161: BCD to seven segment decoder/driver, CA3162: A/D converter for 3 digit display, LM 7805: 5-volt regulator: BC640: PNP transistor, Resistor: 1/4 watt power rating, Capacitors: mylar ceramic and electrolytic, Diodes: IN 4148 and B40C1000, 7- segment LED display, Philips humidity sensor and power on-off switch.

The digital hygrometer was constructed on a specially designed PCB. Complete circuit diagram of digital hygrometer is shown in figure 1.

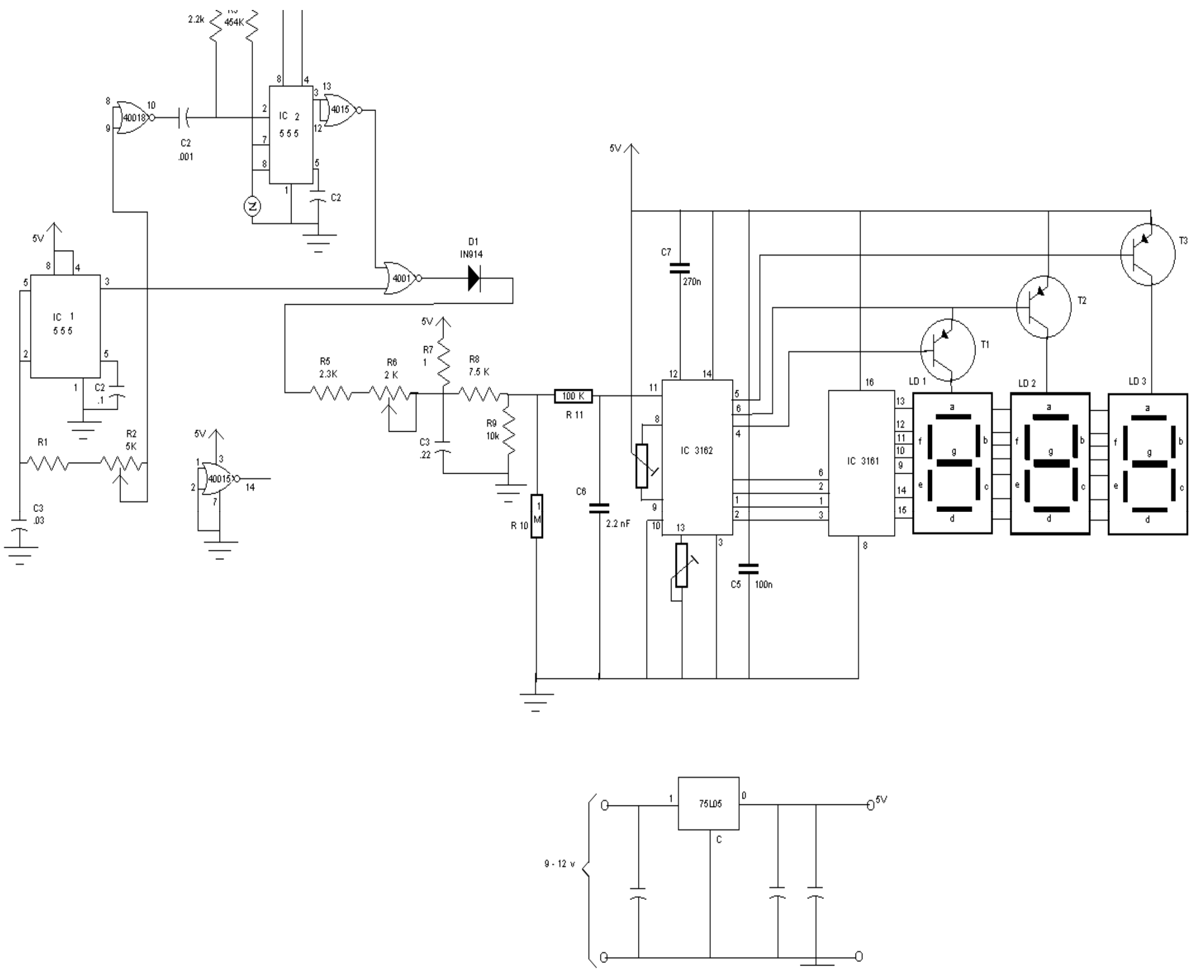

Fig. 1. Complete Circuit diagram of the Fabricated Digital Hygrometer

Table 1. Recorded values of Relative Humidity (RH %) for the Standard and the Fabricated Hygrometers under the same Ambient Temperature conditions and their differences

Day	Time	Ambient Temperature	Standard Digital Hygrometer Readings	Fabricated Digital Hygrometer Readings	Difference	
	Hours	^oC	RH % X_1	RH % X_2	d_i $X_2 - X_1$	d^2
Day 1	08.00	18.4	48.2	47.6	–0.6	0.36
	11.00	36.0	27.3	30.1	+2.8	7.8
	14.00	33.0	24.0	24.4	+0.4	0.16
	17.00	25.0	36.3	38.1	+1.8	3.2
Day 2	08.00	18.7	47.5	47.8	+0.3	0.09
	11.00	37.8	26.4	28.0	+1.6	2.56
	14.00	39.0	24.9	23.9	–1.0	1.00
	17.00	25.2	31.6	35.0	+3.4	11.50
Day 3	08.00	18.2	43.6	47.0	+3.4	11.5
	11.00	35.0	27.0	28.0	+1.0	1.0
	14.00	33.2	27.0	28.3	+1.3	1.69
	17.00	25.8	32.2	32.1	–0.1	0.01
Day 4	08.00	18.5	55.6	60.0	+4.4	19.36
	11.00	36.9	23.9	30.0	+6.1	37.2
	14.00	32.2	27.5	27.0	–0.5	0.25
	17.00	27.2	31.2	33.0	+1.8	3.24
Day 5	08.00	19.6	45.2	46.0	+0.8	0.64
	11.00	29.8	28.9	28.0	–0.9	0.81
	14.00	28.0	30.7	34.0	+3.3	10.89
	17.00	24.4	37.5	39.0	+1.5	2.25
Day 6	08.00	19.2	54.2	53.9	–0.3	0.09
	11.00	24.0	39.1	46.0	+6.9	47.6
	14.00	24.6	37.2	36.4	–0.8	0.64
	17.00	23.2	44.6	48.7	+4.1	16.81

Circuit operation

One NE 555 IC (labeled as IC1 in the diagram) is used as 7 KHz astable oscillator. While another NE 555 IC (labeled as IC2) as monostable multivibrator. The output of IC1 is inverted by IC3-a (NOR gate) which provides trigger pulse that drives the IC2.

The output signal of IC2 is inverted by IC3-b (NOR gate) and combined with IC1 signal through IC3-c, which allows to pass only the difference between the two signals to the detector circuit. The detector circuit is composed of diode D1, the resistor R5 toR9 and a capacitor C5. The pulses from IC3-c are rectified and filtered into DC voltage that is proportional to relative humidity. Full scale meter adjustment is provided by R6 and R8. R9 functions as voltage divider that scales the output to exactly 1 volt at 100% relative humidity.

The common anode connections of seven segment displays LD1, LD2 and LD3 are successively connected to the positive 5 volt supply line via transistors T1, T2 and T3. The potentiometer P1 (pin8 and pin9) is used for zero adjustment. Potentiometer P8 (pin13) is used for gain adjustment.

IC5 (CA3162) is analogue to digital converter which gives the output in the form of binary coated decimal which are directly connected to IC6 (CA3161) which in turn drives the three common anode seven segment displays. The seven segment display shows the relative humidity.

The relative humidity was recorded in the range of 20% to 60% at ambient temperature (Cao and Huang, 2001). The data obtained was compared with a standard hygrometer obtained from the Meteorology Department, University of Agriculture, Faisalabad.

RESULTS AND DISCUSSION

Performance of fabricated digital hygrometer was studied by comparing its relative humidity readings with a standard Thermo-hygrometer model HD-600 (Japan). This model is microcomputer based and a polymer humidity sensor is used in it.

The recorded observations along with the differences are given in table 1. The data for relative humidity was recorded using both hygrometers under exactly identical conditions.

T-test was applied to check the mean differences of paired values. The value was found to be 1.6875. The standard deviation of the difference of paired values was 2.212. The difference between fabricated digital hygrometer and standard hygrometer was found to lie between 0.753 and 2.622, which corresponds to confidence interval of 95%.

Table 2. Frequency table for the relative humidity differences between Standard and Fabricated hygrometers

Relative humidity differences between standard and fabricated hygrometers	Frequency f	Percentage
Greater than 3	7	29.1%
Between 2 and 3	1	4.2%
Less than 2	16	66.7%

The relationship between positive and negative differences at low and high relative humidity levels are given in table 3. The percentage between positive and negative differences was 71%: 29%. This ratio indicates that the percentage prevails approximately over low and high humidity levels. This shows that the hygrometer is suitable for measuring the relative humidity.

Table 3. Relationship between positive and negative differences at low and high relative humidity levels

Standard hygrometer	***Difference between observations***		***Total***
	Positive	Negative	
Low humidity i.e.<31.9 RH	9 (75%)	3(25%)	12(50%)
High humidity i.e.>31.9 RH	8 (67%)	4(33%)	12(50%)
Total	17 (71%)	7(29%)	24(100%)

The response time of the fabricated hygrometer was less than 5 s which is better as compared to porous fiber based sensor (Ding *et al,* 1991) and twice as good as compared to the porous silicon based dielectric sensor (Das et al, 2003).

CONCLUSIONS

The fabricated portable digital hygrometer was found to be suitable for measuring the relative humidity of air. It is easy to operate, gives direct measurement in short time. The power consumption is low. It can very effectively be used in agriculture industry, in solar energy experiments, in paper industry and in cold storages etc. Its fast response also makes it useful for the applications relating to the respiration measurements. It works in the intermediate range 50-55% which makes it very feasible instrument. It is a very useful equipment, when used by the end-user (farmer). He can keep his materials fresh by keeping the required level of humidity, especially in case of grain storing.

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