

Design and Implimentation of a Microcontroller Based Digital Thermometer

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Abstract: In the field of healthcare, temperature monitoring has assumed a very vital role both in the management of patient's condition and general hospital storage facilities. Current advancements in the technology of temperature measurement have led to a huge variety of sensors and measuring instruments now being available for making accurate measurements. Most of the types available locally are the analogue type. In this work, a digital thermometer has been designed and constructed based on ATmega16 microcontroller using LM35 as the temperature sensing device. The design is in four modules; power supply, temperature sensor, LCD device and ATmega16 modules. While the ATmega16 forms the main control element, the temperature sensor senses the temperature to be measured and converts it to a corresponding analogue voltage. The measured temperature is displayed on a 16 by 2 Character LCD incorporated in the system. The system was tested and the results showed a mean deviation of $\pm 0.5^{\circ}\text{C}$ from the readings when compared to a standard digital thermometer (ST-9269 MULTI-STEM THERMOMETER) reading. The thermometer is most suitable at higher temperatures.

Keywords: Design, microcontroller, thermometer, LCD, Temperature.

I. Introduction

The name thermometer is coined from the Greek words thermo meaning "warm" and meter, "to measure" (Wikipedia, 2011). Thermometers measure temperature, by using materials that change in some way when they are heated or cooled (Bellis, 2011).

The invention and creation of the first working thermometer has been credited variously to Abu Ali Ibn Sina, Cornelius Drebbel, Robert Fludd, Galileo Galilei and Santorio Santorio (Helden, 1995; Sigurssen, 2003; Wikipedia, 2011). Modern thermometers are calibrated in standard temperature units such as Fahrenheit or Celsius and Kelvin. A thermometer has two important elements: the temperature sensor in which some physical change occurs with temperature, plus some means of converting this physical change into a numerical value (Wikipedia, 2011). The temperature precision or resolution of a thermometer is simply to what fraction of a degree it is possible to make a reading.

In this paper a digital thermometer was designed and constructed using AVR microcontroller device. The block diagram for the thermometer is as shown in fig 1. The design is in four modules; power supply, temperature sensor, LCD device and ATmega16 modules. While the ATmega16 forms the main control element, the temperature sensor senses the temperature to be measured and converts it to a corresponding analogue voltage. The digital value of the measured temperature is then displayed on an LCD device. The power supply section provides the required voltages for the other three sections.

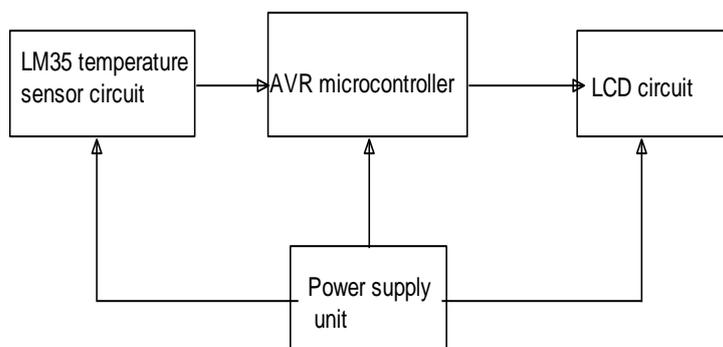


Figure 1: block diagram of the digital thermometer

II. Design

Power Supply

The power supply requirements for the three sections of the project are all 5V (LM35 Data sheet, 2006; ATmega16 Data sheet, 2007; LCD data sheet, 2000). An LM7805 voltage regulator was used to provide steady 5V supply for the three sections. For the voltage regulator to regulate properly provision must be made for drop out voltage. For this reason the input voltage to the regulator is specified (LM7805 Data sheet, 2011).

$$7V \leq V_{in} \leq 20V$$

A 9V battery was used as the input voltage to the regulator.

The supply connections to the various sections is shown in Figure 2

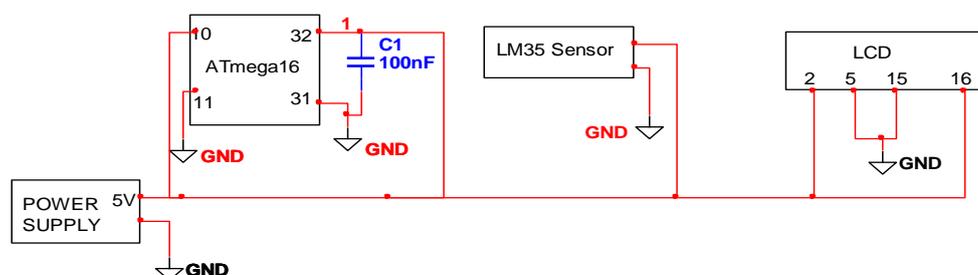


Figure 2: The supply to the various sections

Lm35 temperature sensor circuit

The fundamental necessity of the research is the conversion of the measured temperature into a corresponding electrical signal. There are many transducers capable of performing this, among which are thermocouple, thermistor and LM35 IC series. For convenience, availability and many inherent advantages a version of the LM35 series is chosen for this project.

The LM35 series are precision integrated-circuit temperature sensors, whose output voltages are linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over other temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming and has low output impedance, linear output, and precise inherent calibration that make interfacing to readout or control circuitry especially easy. As it draws only 60 μ A from its supply, it has very low self-heating (LM35 Data book, 2010).

One common temperature sensor in the LM35 series available in the market is LM35DZ. There are other temperature sensing components in the same series like LM334, DS1820 etc. This project has made use of the LM35DZ; this is because of its availability and the range of temperature it can handle. The LM35DZ is a precision semiconductor temperature sensor giving an output of 10mV per degree Centigrade rise.

According to its data sheet (LM35 Data book, 2010) an RC circuit should be connected across the output and ground of the LM35DZ, if a long cable is used. This is to reduce the capacitive effect of the cable. A capacitor of 1 μ F and a resistor of 100 ohms were connected across the IC as shown in figure 3

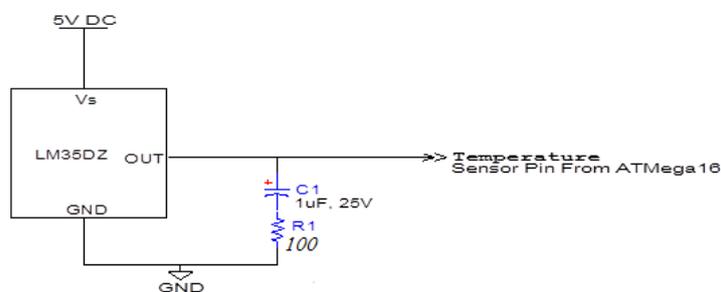


Figure 3: LM35 sensor circuit

LCD circuit

The LCD employed is a 16 x 2 type capable of displaying 32 characters in alphanumeric form. It has a wide range of LCD driver power from -3 to 1V with high speed MPU bus interface of 2MHZ when the supply voltage is $V_{cc} = 5V$. It can also be configured as 4 bit or 8 – bit interface enabled to transmit or receive data in either 4 bits or 8 bits. It consumes very small power with automatic reset circuit that initializes the controller/driver after power on. Internally there is an oscillator that has external resistors (LCD Data book).

The LCD was configured to drive its dot-matrix under the control of 4- bit output of the microcontroller. A regulated supply of 5V was used to supply the chip which is within the recommended supply voltage of the chip. A 100Ω resistor was included as a current limiting resistor. The pin 16 of the chip is the V_{cc} while pin 1 is the ground and was connected to the 0 line of the supply. Since only four bits are used to receive data from the micro, the upper nibble of the byte line was used while the lower nibble (D₀ to D₃) was connected to the ground as recommended in the data sheet. To achieve this, pins 7, 8, 9 and 10 (upper nibble) were grounded while pins 11 to pin 14 (lower nibble) were connected to receive the 4-bit data from the main micro. A variable resistor is provided to adjust the brilliance of the LCD. The value as recommended in the datasheet is from 10k to 30k. For this project, a 10k variable resistor was used to vary the brightness of the LCD. Pin 5 of the LCD is used as the enable pin to activate the device and set it for operation. Pin 4 is the reset pin that is used to clear the registers of the LCD. The data transfer from the microcontroller is completed after the 4 bit data has been transferred twice. The order of transfer is that the four lower order bits (D₄ to D₇) are transferred before the four higher order bits (D₀ to D₃).

The circuit configuration of the LCD circuit is as shown.

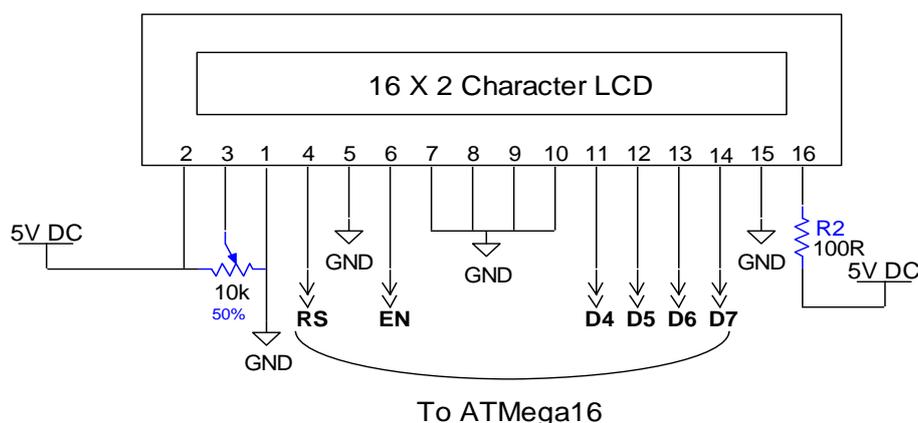


Figure 4: The LCD circuit

ATmega 16 AVR circuit

The heart of the system is the AVR microcontroller. It is a 40pin dip used to control the activities of all other sections. ATmega16 AVR was selected due to its good features of being cheap and readily available in the market it also has high performance low power consumption 8 bit operation with 130 powerful instructions. The symbol and pin connections is as shown in Figure 4

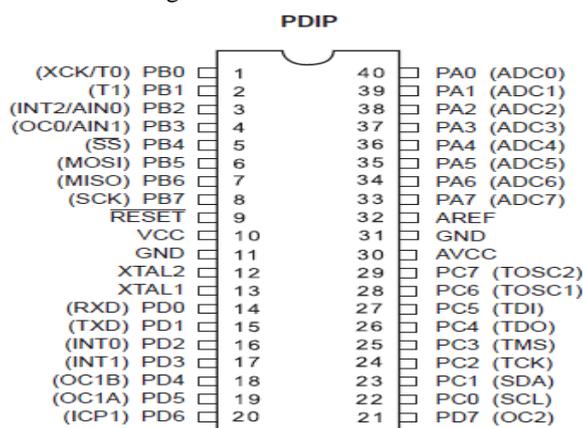


Figure 5: ATmega16 symbol

Pins 12 and 13 serves as the crystal input and output of an inverting amplifier and it is configured as an On-chip oscilliator. The connection as specified by the data sheet is as shown

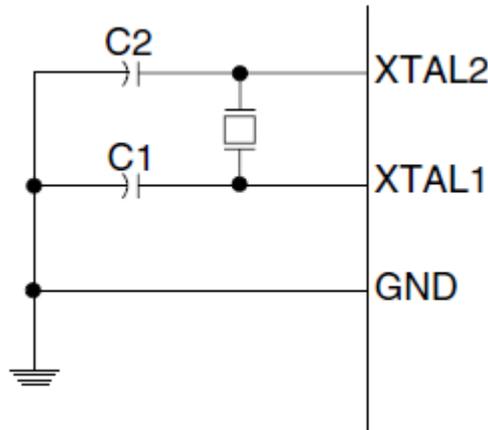


Figure 6: Microcontroller oscillator

It is recommended (ATmega16 data sheet) that the values of the capacitors be in such a manner that $C_1 = C_2$

And that the value should be between 12 and 22 pF.

For these reasons we used 2 numbers of 22pF capacitors and a crystal of value 11.0592 MHz

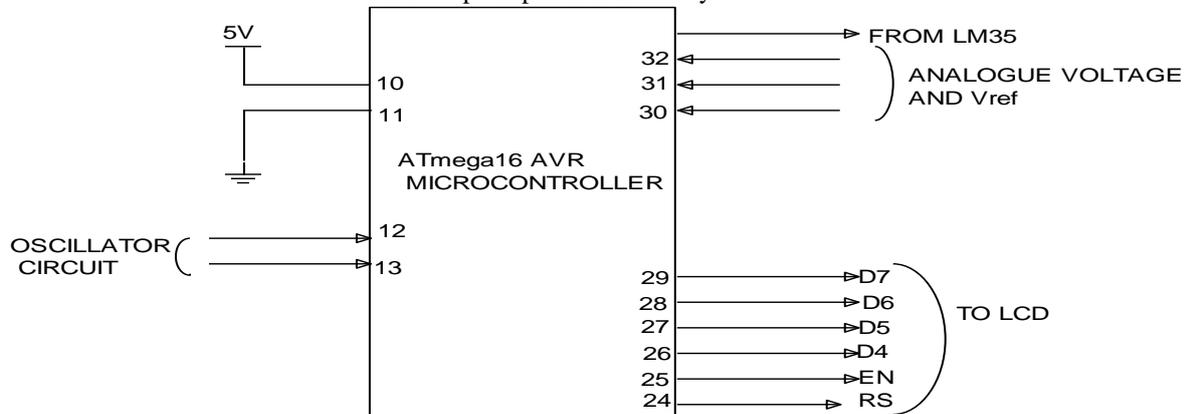


Figure 7: ATmega 16 circuit

The temperature condition at any instant as sensed by the LM35 is displayed on a Liquid Crystal Display (LCD). To do this the ATmega16 is programmed to copy the output of the ADC and convert the result to ASCII then transferred to the LCD to be displayed. The flow chart below shows the software algorithm of the AVR microcontroller.

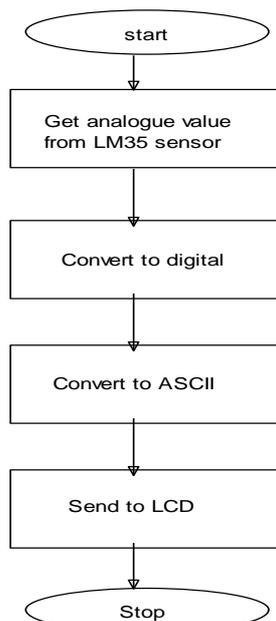


Figure 8: ATmega16 software flow chart

III. Circuit Construction And Testing

LM35 circuit.

The LM35 temperature sensor circuit was constructed using the following components;

Table 1: LM35 list of components

S/N	Component	Description	Quantity
1	Temperature sensor	LM35	1
2	Capacitor	1uF	1
3	Resistor	75k	1
4	Wires	Twisted	

The LM35 circuit was constructed with the capacitor connected very close to the IC. The wires were covered up with a tape which will ensure that the leads and wires are all at the same temperature at the surface, and that the LM35 die's temperature will not be affected by the air temperature to ensure accuracy. The wire was twisted together to reduce the length hence making it more convenient and beautiful. The constructed temperature sensor is shown as in plate 1



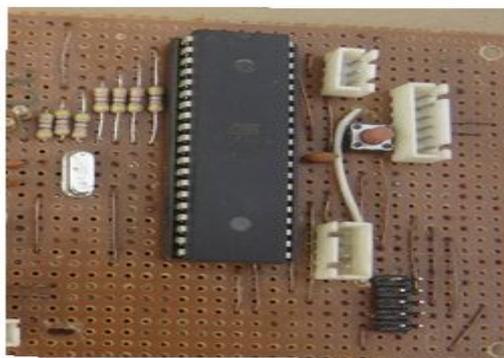
Plate 1: constructed sensor circuit

Table 2: ATmega16 module list of components

S/N	Components	Description	Quantity
1	Resistors	4K7	9
2	Capacitor	22uF	2
3	Capacitor	100nF	1
4	Crystal	11.0592MHZ	1
5	Microcontroller	ATmega 16	1
6	Connector	4 wire	1

The main microcontroller circuit was constructed on a board as shown in plate 2.

A 40 pin socket was first soldered to the board then the IC was plugged in. This allows for easy maintainability as they could easily be replaced.



Main microcontroller circuit

Plate 2: ATmega16 module

THE LCD CIRCUIT CONSTRUCTION

The LCD display unit circuit was constructed on the circuit board using the components listed below.

Table 3: LCD circuit list of components

S/N	Components	Description	Quantity
1	LCD	16 x2	1
2	Capacitor	100Ω	1
3	Resistor	10K	1

The constructed LCD circuit is shown in plate 3. The components were placed at the back of the board for casing purpose.

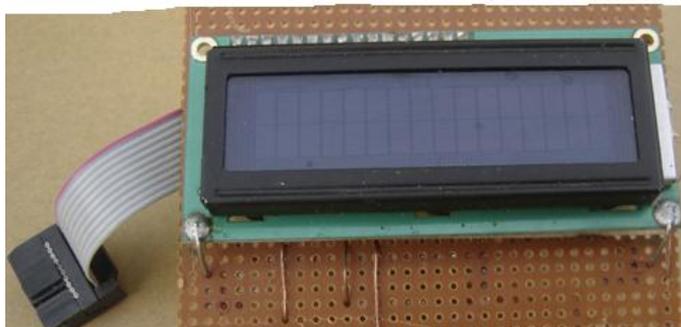
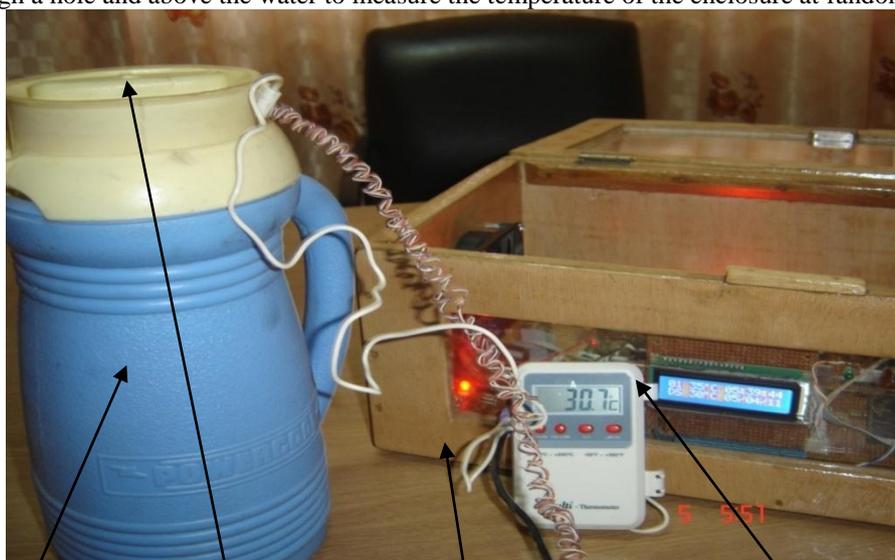


Plate 3: The LCD constructed module

THERMOMETER TESTING

To test the accuracy of the constructed thermometer a digital thermometer type (ST-9269 MULTI-STEM THERMOMETER) was obtained and used to conduct an experiment to compare the temperature measurements of the two. The jug as shown in plate 4 was half filled with hot water and the two sensors were inserted through a hole and above the water to measure the temperature of the enclosure at random intervals.



Water jug Inserted sensors Digital thermometer constructed thermometer
Plate 4: Set up of experiment

IV. Results

The result of the experiment to compare the accuracy of the constructed thermometer is tabulated in table 1

Table 4: Temperature of the two thermometers

System temp (°C)	Digital temp (°C)	difference
33	33.2	0.2
38	37.9	0.1
40	39.7	0.3
42	42.5	0.5
46	46.3	0.3
48	47.9	0.1
50	50.0	0.0
52	52.3	0.3
56	55.9	0.1
57	57.1	0.1

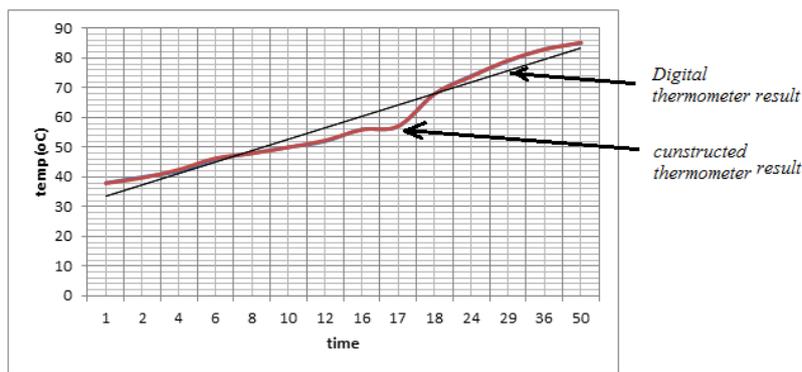


Figure 9: A plot of the measured temperatures against time.

V. Discussion

As could be seen from the table the difference ranges from 0.0 to 0.5. The results obtained as tabulated show that there are small deviations between the two temperatures. The possible reason for the slight difference in the measured temperatures is that the resolution of the ADC is 1⁰C. This means that temperatures are rounded up to the nearest whole number during ADC conversion process. The measured temperature is therefore likely to have error of 0 to ± 0.5 ⁰C from the actual value. The percentage error is significant at low temperature and negligible at higher values.

VI. Conclusion

In this manuscript, a digital thermometer has been designed using an AVR microcontroller as the heart of the system. To sense the temperature to be measured and LM35 sensor was employed. The measured temperature is then converted to digital format by an ADC located internally in the AVR microcontroller and displayed on an LCD.

It is suggested that this thermometer may be improved upon by using a more sensitive sensor to make it suitable for measurements at lower temperatures. A memory device may also be incorporated to store the measured results.

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