Automotive Engine Temperature Control Employing Apt Temperature Measurement And Control Measures.

Mr. G.V.BHARADWAJA SARMA[1].   Mr. CH.NAGARAJU [2]

M.Tech, Embedded systems, AITS,   Department of ECE, AssociateProfessor
Rajampet, Kadapa (Dist.)   AITS, Rajampet, Kadapa (Dist.)

ABSTRACT

Measurement of the temperature around an automotive engine is very important and one of the contributing character in improving an automotive engine's performance and life time. The method of measuring the temperature is a tricky aspect which has to be done in a suitable else the measurement method may give inappropriate understanding about the temperature around the engine. Measuring the characteristics of temperature is an important technologic process to improve the quality of automobile products and work efficiency. In this paper an embedded temperature characteristics measurement system for automotive temperature sensing is designed employing AT89C55 as kernel and pre-emptive real time embedded operating system µC/OS-Ⅱsoftware platform which gives the system the capability of multitasking in real time and meets the needs of the prototyping.

Key words: ECU, UART, thermistor, temperature sensor, kernel µC/OS-Ⅱ, system setup, AT89C55, prototype.

I.INTRODUCTION.

Temperature characteristic is an important performance of thermistor based automotive temperature sensor, so measuring the characteristic is an important technologic process to improve the quality of automobile products and work efficiency. In this paper, an embedded resistance-temperature characteristic measurement system for automotive temperature sensor is designed, which uses AT89C55 chip as kernel and preemptive real-time embedded operating system µC/OS-Ⅱas software platform. The system has the capability of multi-task real-time scheduling and completely meets the need of real time and reliability.

The system uses computer technology as basis, AT89C55 chip as control kernel and real-time kernel embedded operating system µC/OS-Ⅱas software platform. Finally a highly efficient, accurate and reliable automatic measurement system is constructed. The temperature value is measured and it is displayed on Graphical [13] LCD display and the devices like keypad input is also fed to Atmel processor and serial data also transmitted

through the UART to the PC using RS 232 communication. Modern automotive engine generally uses special coolant as cooling medium. Temperature of coolant is measured by temperature sensor which is equipped on the engine cooling water jacket. The result is then sent to ECU (Electronic Control Unit) in order to display and control the coolant temperature of the automotive radiator [1].

Almost every type of automobiles generally use thermistor based temperature sensor to measure the coolant temperature. In order to accurately measure the temperature sensor must be ensured. Use of thermistor helps measuring the resistance-temperature characteristics as no other sensor devices employs measurement of temperature according to the resistance concept.

II. METHODS OF MEASUREMENT.
i.THERMISTOR CONCEPT:

Here in the concept of thermistor it has an intriguing feature which gains its advantage over the other methods of measurements. Thermistor can help us find the temperature around the whole engine whereas in other methods the measurement is done with respect to a single position where the sensor is being placed.

The use of thermistor can be done in many ways as its compatible with many situations unlike singe IC sensor, as the thermistor is a piece of semiconductor which can be molded in a sheet, piece, disk, wafer and any other shapes. Thermistors are of 2 types NTC thermistor [2] (Negative Temperature Coefficient), PTC thermistor (Positive Temperature Coefficient).If we employ thermistor the coolant temperature measurement circuits [1]and circuit are as follows.
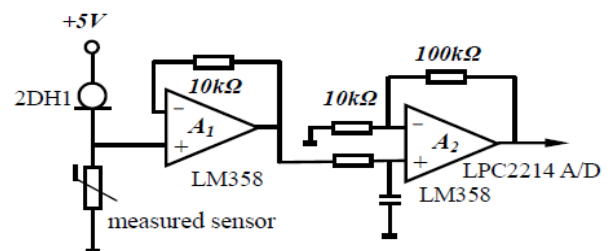

Fig.1coolanttemperature measurement circuit.

The coolant temperature measurement circuit is a temperature/current/voltage/Celsius temperature conversion circuit, which contains temperature sensor AD590, voltage regulator, voltage follower and a differential amplifier .the temperature sensor integrated circuit AD590 [11] is a kind of temperature current sensor which has fine linear performance, high stability and sensitivity and no need for compensation.

Automotive temperature sensors mostly use negative temperature coefficient thermistors as the sensing element. Measuring the temperature sensor is vitality to measure its resistance, which can be implemented by resistance voltage conversion circuit. The above circuit employs LM358's. Here a constant current source is added to the sensor to convert its variation of resistance to variation of voltage then the signal is sent to A/D port of the microcontroller for processing the signal through conditioning circuit.

ii. Use of lm35 sensor.

Here in this approach the use temperature sensor LM35 [4] for sensing the temperature is done. The use of this sensor would make the measurement of temperature slightly calculative than the thermistor method but makes the prototyping easy.
Here in this paper the presentation of the prototype model which measures employing LM35 is done.

III. APPROACH BASED ON LM35.

The entire table set up of the prototype model using LM35 is shown in the following figure. This set table top setup (prototype) employs a heater (submersible) of 750 Watts for production of heat to raise temperature. This heater is placed in a metal container with 5mm plastic coating, AT89C55WD[14] microcontroller, LM555 timer, ADC 0808, OP-AMP op-07, CON14A LCD, LM7805/TO220 voltage regulators[14], 12V SPDT relays[14].

Here for the cooling purpose a 1200 RPM fan and a 5HP induction motor are used. Where the fan rotates to cool off the coolant and the motor circulates the coolant around the heat source to reduce the temperature. Coolant used here is water (to check the basic prototype model).
The LCD employed is 16×2 CON14A,[12] which means it is capable of 16 characters in a line and supports two lines.

AT89C55WD [3] is a microcontroller with 20KB of In-System Reprogrammable Flash Memory- Endurance: 1,000 Write/Erase cycles. It is fully static operation capable (0 Hz to 33MHz), three level program memory lock, 256×8 bit internal RAM, 32 programmable I/O lines, three 16 bit Timer/Counters, eight interrupt sources, low power idle and power down modes. ULN 2003a[12][13] is used for relay driving purpose which interfaces fan and circulation motor to 230V power supply as well as protects the microcontroller from being damaged by the backlash of high voltage.

LM35 temperature sensor has an output voltage linearly proportional to the Celsius temperature. The scale factor is +10.0mV/ ^{o}c scale factor, 0.5 ^{o}c accuracy guarantee able, rated for -55 ^{o}c to 150 ^{o}c range, suitable for remote, low cost due to water level trimming, operates from 4 to 30V, has less than 60µA current drain.LM35 can measure temperature more accurately than a thermistor based temperature sensor; LM35 produces a higher O/P voltage than a thermo couple hence it does not require O/P voltage to be amplified.OP AMP - 07a[12][5] is employed here to amplify the signal from the temperature sensor and give it to ADC which receives its count for time from LM555 timer. The o/p from the ADC is sent to microcontroller Port 0, Port 1.

The schematic setup that is embedded in ECU is shown as follows. The schematic employs all the above mentioned components.
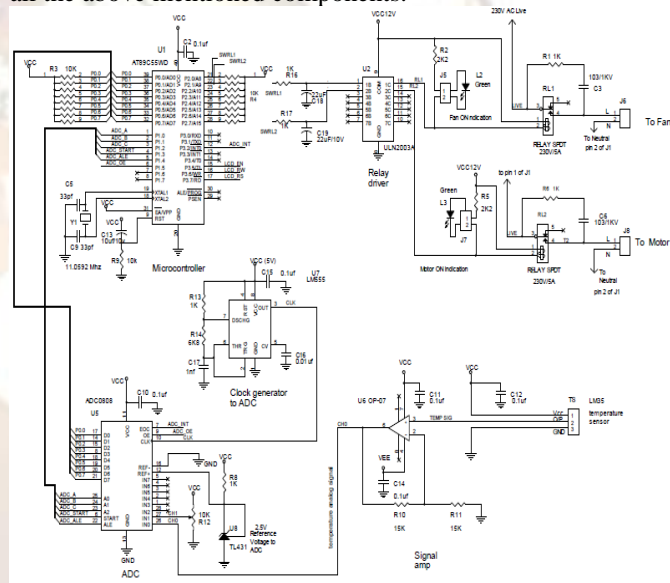

Fig.2 The schematic embedded in ECU

IV. PROTOTYPE MODEL SETUP:
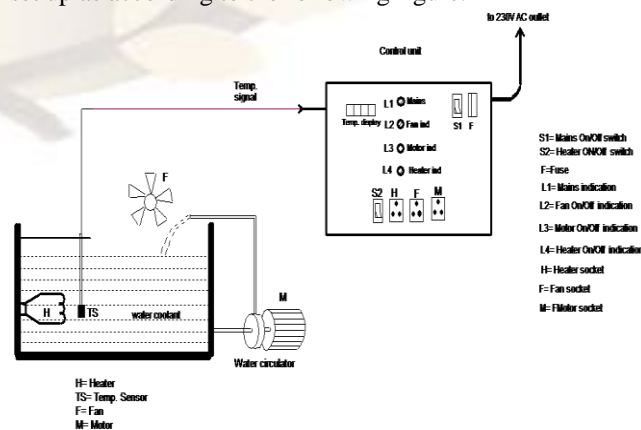The prototype model designed has a table top model set up as according to the following figure.

Fig.3 Prototype of Method employing LM35.

Here in ECU the controls for fan and the induction motor are controlled by the (kernel) microcontroller. But the heater is not controlled by the microcontroller as in an auto motive the heat production takes place when the engine is ON and running i.e.., when the heat production is going on. So the cooling mechanism has to be controlled by the kernel part in the microcontroller. Hence the heated is powered on independently. The coolant used here is water and it is filled up to two thirds of a 15 liter container. An outlet for the coolant is made which connects to the induction motor and again back to the container from the open top side. The induction motor circulates the coolant and the fan above the container cools the water flow in to the container and the water surface in the container.

In this model testing is done in a step wise manner.

a. When the ECU is powered is on firstly the sensor records its first reading of temperature of water.
b. Then the heater is powered.
c. The sensor keeps recording the values and when it reaches the higher limit set in the code (here 54.5 ^{o}c) the micro controller activates the relays.
d. The relays in-turn activates the fan and motor to initiate the cooling mechanism.
e. The sensor keeps recording the values and if the temperature values reach lower limit set (here 45.5 ^{o}c) the relay is de-powered.
f. So the fan and motor are turned off, this is done in order to save power.
g. The readings of temperature are still monitored and if it is found that the temperature has reached 54.5 oc then again the 'step c' is reached.
h. This is an automatic cyclic process.

But the achievement of the lower limit is possible only when the heat production is stopped i.e. engine is kept idle, but when it is kept running the heat production is un-hindered the cooling mechanism will continue till the engine is stopped. Due to this (constant circulation) the temperature is reduced by 6 to 7 ^{o}c and maintained there. If the engine still is kept running the temperature rises by 1 ^{o}c for 45 min. In this way if the engine is kept running it would take hours to get to maximum limit of temperature and if the maximum limit itself is set to 5 to 10 ^{o}c below the engine maximum heat limit for break down then it would take eight more hours for the engine to break down due to overheat. In this way the engine's working duration can be safely extended and hence contribute to the engine's life time.

The prototype model when under working, the circulation of coolant is done from the container to the container by induction motor and cooled by a fan with 1400 RPM speed. (Employment of AC sections available in cars can provide a better cooling mechanism).

Fig.4 Prototype model while circulating.

An improvement that would help in further enhancement of model could be considered from an railway locomotive engine, where the huge engine is wounded by coolant carriers and there are super air cooling chambers present along the length of the coolant carrier pipes that gives a lot of cooling. Here one thing about the railway locomotive is that the heat generated is proportional to the load it carries (the concept of variable load comes into play which is not introduced in this prototype model). Some time when the load is too much to pull over the generated from the engine would evaporate the water and cause steam pressure in the pipes which is undesired. Hence to overcome this they employ steam alarms to identify such situation and they slow down the engine in-order to reduce the load which in-turn reduces the heat production. Here the concept of variable load is not involved as it would take the prototype long way from basic model understanding.

Fig.5. Prototype model.

1) MATERIAL PROPERTIES OF THE MATERIALS USED:
a. METAL CAP COVERING FOR TEMPERATURE SENSOR:

The metal cap of 12cm long made of mild steel (MS) encases the LM35 sensor. Silicon and quartz shards are carefully packed into the space between the sensor and the metal tube inner walls in order to prevent air existence in the gap which does not transfer the heat from the outside metal body to the sensor body surface. This packing of materials is done in vacuum and sealed off with a good air tight adhesive in order to prevent water from getting into the metal case. The material used to covering the temperature sensor is MS (mild steel) which has a nonlinear way of heat reception and dissipation. Due to these characteristics the heat transfer towards the sensor is delayed this causes the temperature difference of 3 to 5 degree centigrade between water and sensor. Hence the temperature reading is influenced by the property of the metal. Hence it is proposed to employ any encasement of silicon or any other material with a material which has a good heat transfer capability.

b. Coolant characteristics (Water):

The specific heat [6] value of the coolant i.e.., water is 1. Due to this the temperature of the water raises in a uniform way and in equal proportions. This helps in maintaining the temperature close to room temperature. Ambient temperature plays a good role in heat dissipation and heat accumulation. As an effect of ambient temperature heat raise of temperature by 10 or more than ambient value would take more time than the time required for reducing towards ambient temperature.

CONVERSION AND TABULATION:

The voltage to temperature conversion, calculation and error possibility is represented in following table.

temperature conversion table for any temperature 0–125º c

Temperature on the body of LM35 (t)	O/P voltage produced by the sensor= (t x 0.01V)	Amplifier o/p voltage= 2(t x 0.01V)	Equivalent digital count produced by ADC= $\frac{2(t \times 0.01V)}{0.0098}$	Temperature displayed by LCD= $\frac{2(t \times 0.01V)}{0.01} \times \frac{5}{10}$	error	% error
0	0	0	0	0		
0.5ºc	0.005V	0.01V	1	0.5	0	
20ºc	0.20V	0.40	41	20.5ºc	+0.5 ºc	+2.5%
50ºc	0.50V	1.0V	102	51ºc	+1.0 ºc	+2%
100ºc	1.0V	2.0V	204	102ºc	+2.0 ºc	+2%
125ºc	1.25V	2.5V	255	127.5ºc	+2.5 ºc	+2%

Fig.5 shows the tabulation of the voltage to temperature conversion and temperature accuracy rate.

Note: it can be observed that the error of 2% to 2.5% occurs throughout the range of temperature
This design error can be reduced to 0
1. If 10mv x 255 = 2.55V is given to ADC as reference   OR

2. Amplifier gain is adjusted to 1.96 instead of 2 OR
3. by subtracting 2% from the measured value.

RESULTS:

The proposed system prototype is tested and temperature of the around the heart source is maintained 50.5 ºc even though the heat production is un-interrupted. The result images are as follows.
1. The temperature around the heat source is maintained constant for a longer time even when the source is continuously producing heat.
2. The temperature (when observed the) if reaches the preset lower limit temperature then the cooling system is shut down automatically in order to save power.

Therefore the temperature of the heat source (assumed engine) is maintained within the preset range, enabling it to run a longer time without getting over heat and relatively long life

Fig.7The maximum limit which initiatesthe cooling system.

Fig.8 Above picture shows the temperature that is maintained when constant heat production.

v.CONCLUSION:

As per the concept of temperature characteristics measurement and control around the Automotive engine the concept is designed into prototype and tested successfully. This prototype confirmed that better results can be achieved by replacing the coolant with a suitable mixture (proposed to use any condensed coolant which absorbs heat to liquefy and dissipates well). Hence as per the results it can be concluded by controlling the temperature around an engine its working

duration can be safely extended thus increasing its life time.

REFERENCES:

[1] Resistance-temperature Characteristic Measurement System for Automotive Temperature Sensor Based on µC/OS-Ⅱ, Hui Chen IEEE 2011.

[2] Measuring temperature with thermistor by David PotterNational Instruments Corporation.

[3] AT89C55WD Data sheet from datasheet.com

[4] Precision centigrade temperature sensor. National semiconductors

[5] Ultra-soft analog devices. Device specifications data sheet.

[6] OS and its operation By L. Narasimhan.

[7] Thermal and electric properties of materials

[8] Y. X. Zhou and D. G. Huang, "Study of Fuzzy Control System for Engine Coolant Temperature", *Journal of University of Electronic Science and Technology of China*, vol. 38, no. 3, pp. 471 - 475, Mar 2009.

[9] www.fairchildsemi.com

[10] DNA technologies home site.

[11] www.national.com

[12] Maxim catalogs.

[13] www.datasheetcatalog.com

[14] www.ti.com