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Design and Development of Microcontroller Based Engine Cooling System for Auto Mobile Applications

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Abstract **– This paper introduces new approach for the development of engine cooling system to achieve optimal thermal conditions. Thermal cooling requirement of an engine not always related to engine speed, they can be significantly affected by other factors like vehicle velocity, ambient temperature and vehicle loading etc. This paper presents a vehicle engine cooling system, designed around an advanced ARM Cortex M3 based 32-bit RISC processor architecture LPC1768, PT100 temperature sensor and water pump. LPC1768 is an industry leading microcontroller and has intensive on-chip peripherals a large amount of flash memory and static RAM, as well as free development software support. To maximize the benefits of coolant system, temperature sensor is signal conditioned to vary the output as changes in engine temperature occur. The mechanism is directly connectable to crankshaft of a vehicle which decreases the bearing life. The resulting design shows the effectiveness of a low-cost system, also occupies less space. Structure scheme of the hardware with software algorithm described here in shows that system is simple, reliable and has flexible configuration.**

Keywords **– ARM CortexM3 CPU; LPC1768; PT100 Temperature Sensor.**

I. Introduction

Embedded devices can be found in many different applications and industries, example, from consumer appliances like the CD alarm clock that wakes us in the morning to the GPS navigation systems in our cars, and Cell phones and PDAs that keeps us connected. A number of embedded micro components in devices are also growing. A luxury car today has more than 150 embedded microcontrollers and microprocessors in all sorts of applications ranging from engine control mechanism to entertainment devices.

The automotive industry is an important pillar of the world economy. Advanced automation supports manufacturing companies in there strive for increased efficiency and quality optimization. Further the biggest trends in automotive engineering are improving engine efficiency and fuel economy. Some companies are developing optimized and most advanced diesel engines to draw waste heat out of the engine in order to allow the engine to operate efficiently.

Kenneth. J. Kelly described two approaches of engine cooling system where it describes about hybrid electric power inverters with separate cooling loop with water ethylene glycol coolant at 70˚C, the cost of cooling system is reduced by using silicon-carbide switches [1]. Jianwen Shao and his co workers described some experimental techniques for automotive applications, such as motor rotation detection, current sensing with brushless DC motor, which are currently using in power steering, engine cooling fan, fuel/water pump, air conditioning compressor etc [2]. The theoretical model developed for analyzing the heat transfer of automotive cooling system with modular structure links with various cooling system sub models [3]. It was also focused to require much higher performance owing to the improved power output of engines. Engine thermal management system functionality was described with smart thermostat values and variable speed electric pumps and fans [4], [5]. All the above papers described on automotive applications stressing on engine cooling system. But some of them describe on thermal management systems, Motor speed. Efficiency of motor output and so on. But the papers dealing with advanced 32-bit ARM microprocessor are less. ARM is the industry leading RISC processor architecture in the world, dominant in the mobile industry and medical, industrial applications. For future projects designers are looking for the usage of 32-bit microprocessors.

It is typically concentrates on applications of vehicle cooling system based on ARM Cortex M3 (LPC1768). PT100 temperature sensor is used to control the heat engine which in turn reduces the fuel wastage. Our main aim is to reduce the cooling time with low cost, occupying less space with simple hardware and software algorithm.

Thermal energy flows are an important part of a vehicles energy balance. Even in the most advanced engines the vehicle drive uses barely one third of the fuel energy. The task of engine cooling is to draw waste heat out of the engine in order to allow the engine to operate efficiently.

Companies are developing optimized cooling systems by linking them with ECMs, intercoolers and exhaust gas recirculation coolers. On the other hand company engineers are developing thermal management system products based on applied waste heat recovery, heat exchange and other technologies.

A typical cooling system consists of an engine water jacket, thermostat, water pump, radiator, cooling fan, hoses, heater core, oil cooler and overflow, or expansion tank. There are two types of cooling systems: air and water cooling. As the name suggests, air cooling systems involve fans which blow air over the engine block. Heat absorbed by the engine oil is dispersed by an air-cooled oil cooler mounted at a suitable position in the air stream. The noise emission level and the inefficiency in maintaining consistent engine temperatures are considered to be

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disadvantages compared to liquid-cooled engines. Today, air cooling is mainly used for motorcycle engines and in special applications. The oil cooler is a heat exchanger that uses an air-cooling system to maintain the optimized oil temperature of vehicle oils, including engine oil and automatic transmission oil. Water-cooled engines, on the other hand, have passages for the coolant to pass through the engine, absorbing the heat generated so it can be released through the radiator. The cooled fluid is recirculated around the engine while running. Water cooling has become the standard in both passenger cars and heavy-duty vehicles. Instead of pure water, coolants are now a mixture of water (drinking quality), anti-freeze and various corrosion inhibitors. An antifreeze concentration raises the coolant mixture boiling point to allow operating temperatures at a pressure bar in passenger cars. 'Thermal management' means products such as radiators, charge-air coolers and oil coolers that use a medium (air or liquid) to cool the heat that is produced by a vehicle engine.

As the primary component of the cooling module, the radiator includes the radiator core, the coolant tank and all the connections. The radiator core itself consists of a finned tube system with tube headers and side supports. The cores of the coolant radiators in passenger cars are almost exclusively made of aluminum. Aluminum radiators are also being used to an increasing extent in a range of commercial vehicles worldwide. Figure 1 shows the example of engine cooling system.

Rapid development has become an everyday approach to meeting the demands of customers. The combination of computer control and sensor feedback can also compensate for differences in operator driving tendencies and various environmental changes, which can negatively impact engine operating temperatures.

This paper is organized as follows. Section II describes the Technical review of Cooling system and the important features of ARM cortex M3 processor. Section III describes developed hardware and software with modular block diagram. Conclusion and future work is discussed in section IV.

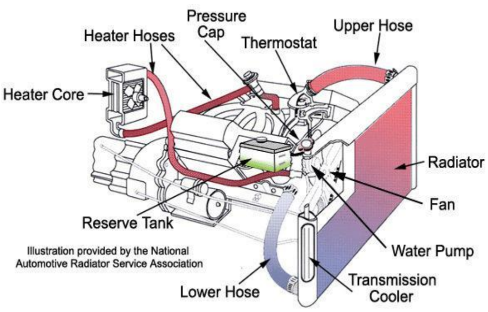

Fig. 1. Vehicle engine cooling system

II. Architecture Overview of ARM Cortex M3 Processor (LPC 1768)

A.ARM Cortex M3 (LPC1768)

ARM cortex M3 core is low power consumption, high efficient 32-bit RISC processor architecture suitable for industrial applications. The MCU is ideal for Brushless DC motor control applications like fan and pumping cooling systems, industrial compressors, printers and motorized tools that require high reliability, operational efficiencies and precise variable speed control. The MCU is very small, have the reduced component count, make it well suited for space critical applications. The device is capable of high speed operation and its extended temperature range enables the processor to be uses in a wide range of industrial applications. Further the combination of industry-standard ARM Cortex M3 CPU with vector engine and high speed timers eliminate a costly DSP, lowering cost of entries for field oriented motor control [6], Lastly the microcontroller supports a built in amplifier for single shunt current detection that can reduce the number of parts and promote cost reduction.

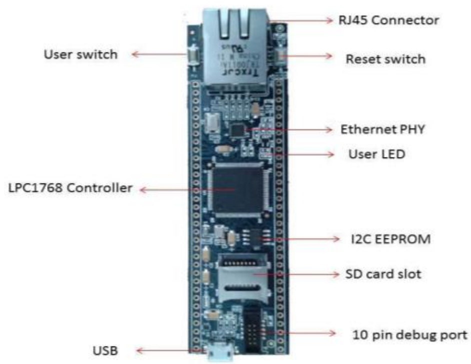

Fig. 2. LPC1768 ARM Cortex M3 based microcontroller

LPC1768 is a low-power mixed signal controller form NXP Semiconductors (PHILIPS). It is an industry leading 32-bit RISC processor with tremendous features such as intensive on-chip peripherals, a large amount of flash memory and static RAM, as well as free development software support [7]. It consists of ARM Cortex M3 shown in fig.2 as its core with 512kB flash memory and 64kB data memory, which offers high level of integration and low power consumption. Salient features of this board include:

Operates in the range of frequencies12 to 100MHz It incorporates a three stage pipeline architecture of 0.91MIPS/MHz (fetching, decoding and running). Harvard architecture with separate instructions, local data buses and a third bus for Peripheral communications.

The important feature of the LPC1768 is that each pin is multiplexed (to reduce the pin-count), and it consists of eight channels of 12-bit ADC namely ADC0.0 to ADC0.7. Key features of the on chip ADC are: [8],[9]

- Measurement range of 0 to Vref (typically3V)

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- 12 bit conversion time ≥ 5µS
- APB clock provides clocking for the ADC

PT100 Temperature Sensor

There are different types of temperature sensors available on the market. Some of them are: Thermistors, Thermocouples, IC temperature sensors, RTDs etc. Thermistors are non linear temperature sensors which call for sensor linearization either by hardware or software. Thermocouples on the other hand need front-end electronics for signal conditioning and compensation circuit etc. PT100 is a temperature measurement RTD sensor. The output of the sensor is signaling conditioned and linearised using a special analog hardware circuit shown in fig 2. The compensation for non linearity is accomplished using the feedback resistor R2 which provides small amount of positive feedback. The reason for choosing PT100 is its long term stability, repeatability, fast response time etc. The output of the linearization circuit is fed to the input channel of analog to digital converter. Its accuracy is ±0.15ºC at 0ºC, temperature range of -200 to +850ºC [10].

A 3-wire lead resistance compensating technique can also be adopted in using the Pt100. In order to obtain the exact temperature, it is of paramount importance to avoid self heating of the sensor which means that the current passing through the sensor should be held low. In the present work, a constant current of 200 µA is passed through the RTD using two channels of REF200, and measuring the voltage drop across the sensor, thus avoiding the self heating of the transducer. The REF200 is an 8-pin IC that has an on-chip dual constant current source/sink and a current mirror. This feature of the IC is exploited in the present work. The voltage drop across the Pt 100 is in the order of micro or mill volt. This voltage is amplified suitably using the linearizing and signal conditioning circuit developed in the laboratory. Fig. 3 shows the signal conditioning circuit of the above description.

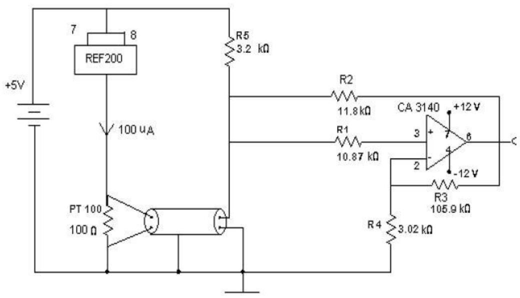
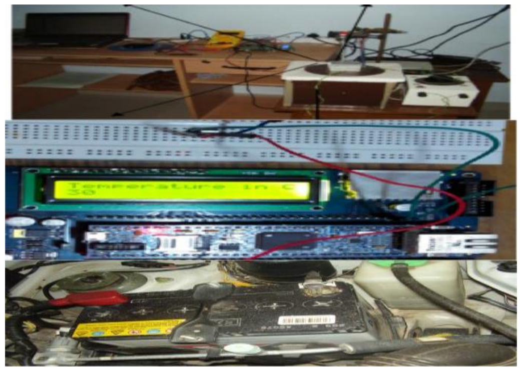


Fig. 3. Signal conditioning circuit for Pt100 temperature sensor

C. *Hardware Description*

The microcontroller processes the selected sensor output to compute and display the parameter value on the LCD module. This is accomplished by connecting data output pin of PT100; the reference voltage to the ADC is the same as the supply voltage to the microcontroller, i.e., 3.3V. The output voltage from the sensor is converted to a 12 -bit digital number and the internal software converts the digital value into its equivalent values and is displayed on the LCD module which is interfaced to LPC1768 in 4-bit mode. Temperature measurements are carried out in the laboratory till 100 ºC to evaluate the cooling system with PT100 sensor. Temperature can be controlled with the software development using embedded C program. When the temperature reaches in the range of 90 ºC to 150ºC , sensor will sense that temperature which in turn displays it on the dash board or computer in the car, then water pump which is connected to the p0.15 of LPC1768 starts circulating the coolant to cool the engine.



Experimental setup with the hardware development is shown in fig 4. The primary job of the cooling system is to keep the engine from overheating by transferring air through the coolant, water pump. The pump is mechanically simple, and thus very robust, it incorporates a nontraditional impeller will meet the high flow and low pressure requirements of typical engines. The design is flexible which can be easily adapted to existing engines by allowing various mounting locations. The pump can generate the appropriate flow rate regardless of engine RPM, allowing the coolant flow to be adjusted as the engine temperature varies. The system has to be developed for reducing fuel consumption and harmful harmful emissions in order to obtaining optimal temperature of the engine.

D. Software Details

The present system is implemented by developing a suitable embedded C program using KEIL µVision software. This is n integrated development environment (IDE) with embedded C/C++ compiler for ARM which supports simulation and debugging interface [11]. The software developed is compiled and uploaded to the flash memory using Flash utility (PHILIPS).

E. Results

The total hardware developed in the present study is shown in Figure 4. In the present study, measurements were carried out between 20°C to 100°C. The temperature values recorded in the microcontroller’s memory is linear fit using ORIGIN software for future calculation in order to maintain the optimal temperature of the engine cooling system.

III. CONCLUSION

In this paper we designed and implemented an ARM microcontroller based temperature controlling system for getting optimal temperature of vehicle cooling system. The developed system is simple, reliable and gives accurate values. With the features such as low cost and better performance, the system can be implemented for reasonably accurate temperature measurement in teaching and research laboratories, automobile industries. The mechanism of the system is simple and low cost, occupies less space.

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