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Design of an Embedded Controller for Some Applications of an Automotives

Dr. Preeti Bajaj and Dinesh Padole
G.H. Raisoni College of Engineering, Nagpur
India

1. Introduction

Developments in Automotive Engineering describes the applications of modern electronics, communications, and control technologies to guide and control of vehicle's operation. Since the last two decades there has been a phenomenal increase in the use of electronic components in automotive systems, resulting in the replacement of purely mechanical or hydraulic-implementations of much functionality. The main motivation behind this is because of fast response, lower cost, reduced weight, new and innovative functionalities, most user-friendly and faster design cycles.

The work presented in the chapter, deals with the design of an Embedded Controller for some applications of an Automotives.

Embedded controller is a special-purpose controller that is embedded in an electronic system. Embedded controllers has major role in modern automobile. There is ever increasing demand being placed on the functionality, complexity and reliability in intelligent transportation systems related to body electronics, vehicle diagnostics, remote access, security, emergency aid, GPS and navigation, infotainment, drive-by services, and fleet management system, torque control, vehicle stability and traction control, electronic control of windows and driver-seat setting, in vehicle communication, entertainment etc.

There are two basic approaches for controlling vehicle functions as shown in figure 1.

Distributed Control

Distributed control, grouped the parameter according to their location & functionality. Each group has their controller and all are communicating with each other accordingly.

Central Body Control

In this approach the main controller managing rage of different functions & can be referred as Central Body Controller. Using this controlling, there is improvement in the sharing of information between different functions to allow better control of body space. Also there are fewer opportunities for overlapping functionality. Such type of architecture provides simplicity, may be effective solution. But this will increases the number of wires with functionality in vehicle.

Multi Core Processor

A multi-core processor is a processing system composed of two or more independent cores. It can be described as an integrated circuit to which two or more individual processors

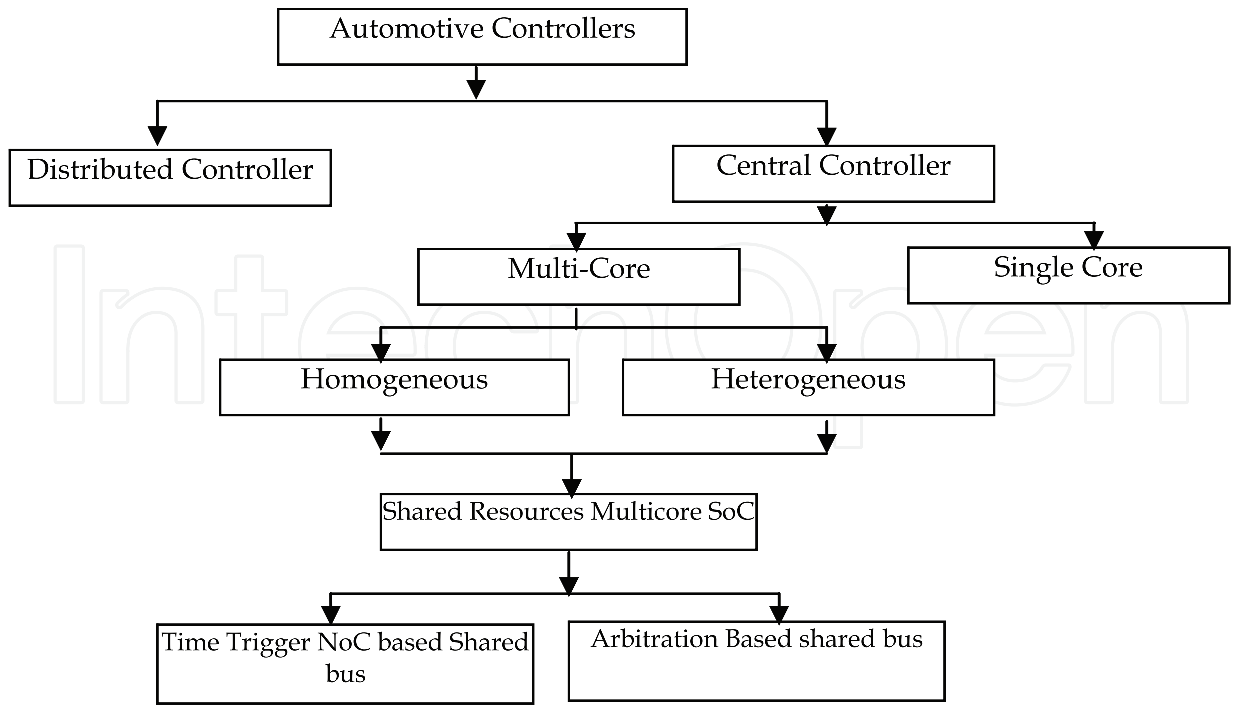

Fig. 1. Various approaches for designing the embedded controller for automotive

(called cores) have been attached. The cores are typically integrated onto a single integrated circuit die (known as a chip multiprocessor or CMP), or they may be integrated onto multiple dies in a single chip package. Cores in a multi-core device may be coupled together tightly or loosely. For example, cores may or may not share caches, and they may implement message passing or shared memory inter-core communication methods. Common network topologies to interconnect cores include bus, ring, 2-dimensional mesh, and crossbar. All cores are identical in homogeneous multi-core systems and they are not identical in heterogeneous multi-core systems. Multi-core processors are widely used across many application domains including general-purpose, embedded, network, digital signal processing (DSP), graphics, etc. study shows that Multicore chips perform better than single core systems. The performance of multicore/ multiprocessor systems depends more on efficient communication among processors and on the balanced distribution of computation among them, rather than on pure speed of processor. Although there are many possible communication architectures, shared bus is very popular in small number of processors system for its simplicity and area efficiency in sharing resource architecture the resources like common buses. Peripheral and memory are shred and utilize by any processor according to need.

Optimum design for an embedded controller can be proposed based on followings design parameters.

- Best arbiter design in term of latency, Master request acceptance rate, Average Waiting Time for master & Average Bandwidth Utilization shared bus.
- Utility of Shared bus.
- Optimum power consumption by embedded controller.

2. Automotive embedded controller.

Controlling In-vehicle gadget with an embedded controller is a very challenging task in Intelligent Transportation system (ITS). Leading electronics manufacturer like Freescale

semiconductor & Intel have established their research wing for automotive controller design.
Proposed Automotive Embedded Controller consists of four master cores. The master cores are Leon processor programmed for Whether Data processing, Digital Image Processing, Battery Controlling and Dashboard Controlling applications. Wiper controller and Air controller core are slave core and don't have processing power. All core are connected with arbiter based AMBA shared bus. Memory is use for the data storage on shared basic to all cores.

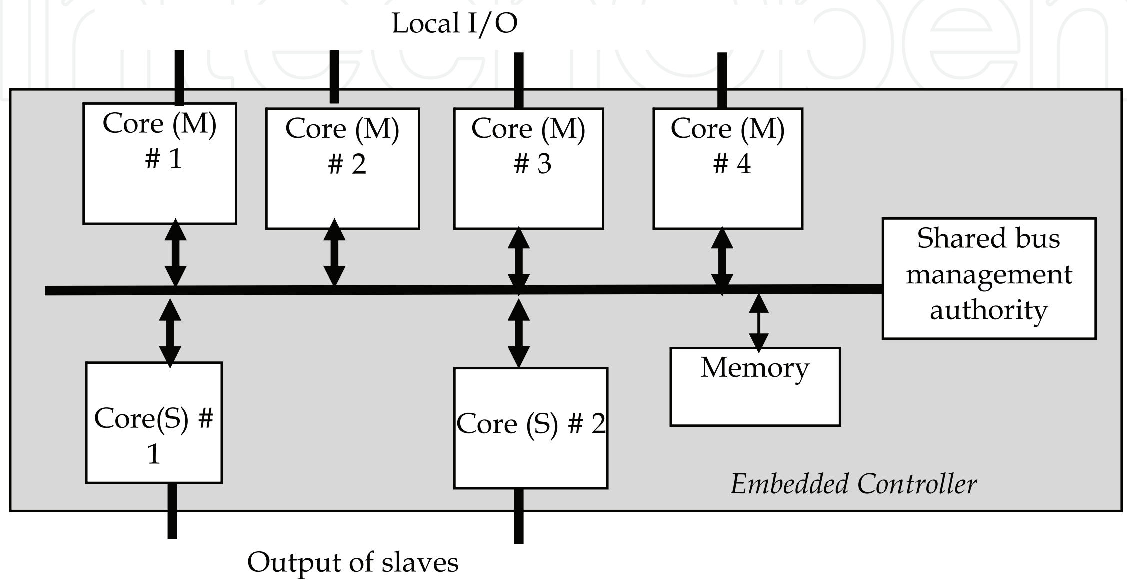

Fig. 2. Shared bus Integrated Multicore Embedded Controller

The integrated Multicore Embedded Controller has following Features

- An Embedded Controller consists of multiple cores with sharing common Bus.
- Cores can be master or slave including memory
- More than one master core.
- Each core are self-sufficient processor with it's Local I/O buses.
- Core may be homogeneous or heterogeneous in nature or architecture
- Core may have different clock speed according to nature of their applications.
- There may be dedicated slave cores for inter-vehicular/ intra-vehicular communication standards communications (eg. CAN, LIN, TTP, FlexRay), User communication standers (Eg. RS232, USB), RF communication (Eg. Bluetooth), standard peripherals (Timers, PPI, Data handling) etc.
- All cores are connected with a common shared bus. Shared bus will consist of Data, Address and Control buses.
- Allocation of bus will be taken care by shared bus management authority.

In figure 2 Core (M) denoted for master core or processor core which can be a self-contained computer with CPU, memory, and I/O interfaces. Alternatively, a core could be an FPGA fabric. Each core is an island of synchronicity, i.e., different cores can operate at different frequencies, which can be changed at run-time in order to effect dynamic power management. Master core are design for different jobs and applications job are rightly assigned to the master core by software. Core (S) denotes for slave core which can be peripheral core. These cores may be of category like programmable peripheral core eg.

Timer, Interrupt controller, Direct Memory Assess etc, peripheral device control core eg. Stepper motor control, DC or may be outside communication standard core like LIN, CAN, FlexRay etc.
Out of the available options LEON processor is chosen for designing Multicore Embedded Controller system because it is highly configurable, fully synthesizable over a variety of platforms, VHDL code freely available under suitable license reasonably good amount of documentation and active online help is available.

Leon Processor:

LEON is a 32-bit CPU microprocessor core, based on the SPARC-V8 RISC architecture and instruction set. It was originally designed by the European Space Research and Technology Centre, part of the European Space Agency (ESA), and after that by Gaisler Research. It is design for embedded applications and are described in synthesizable VHDL. The core is configurable through VHDL generics, and is used in system-on-a-chip (SOC) designs both in research and commercial settings. The architecture consists of AMBA AHB/APB shared bus. New modules can easily be added due to facility of shared bus architecture.

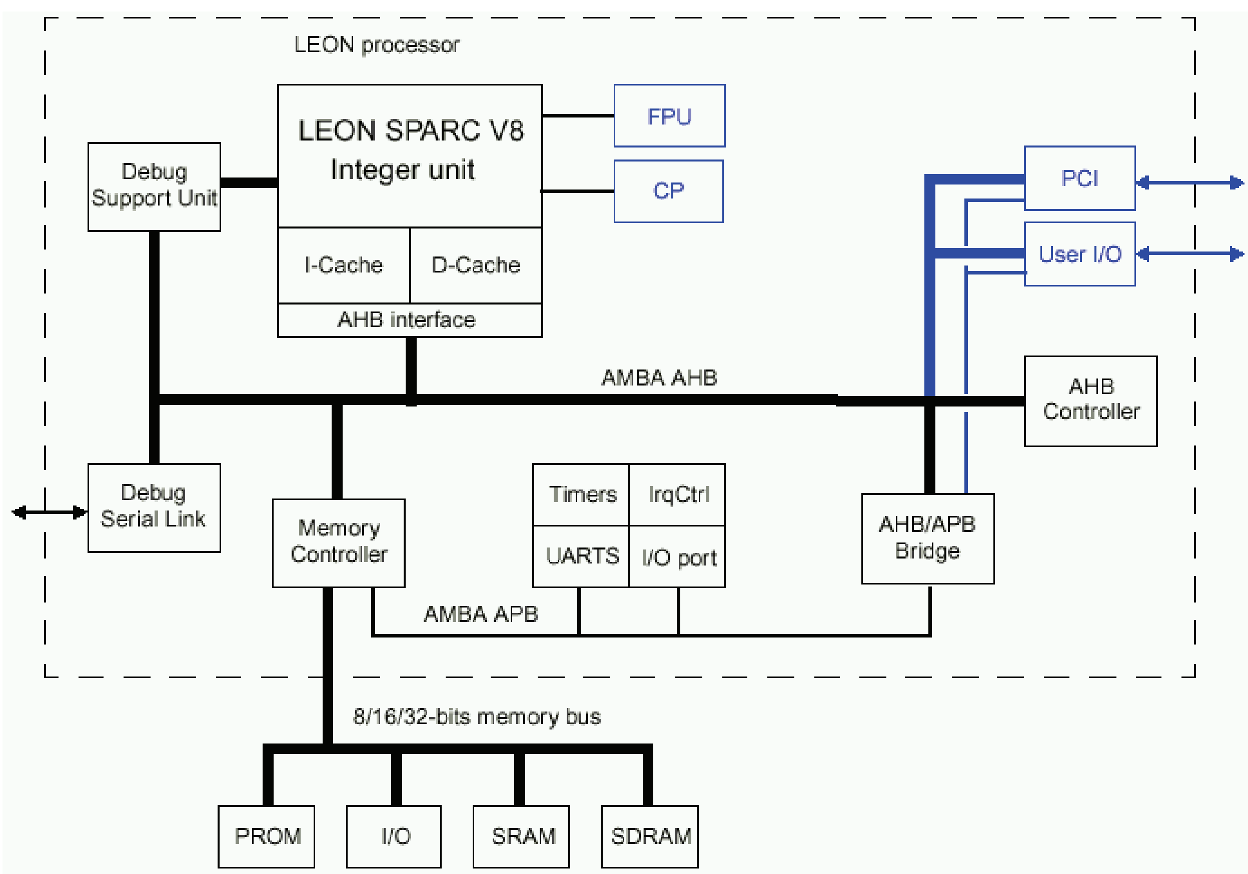

Fig. 3. Block Diagram of LEON2 processor

AMBA Bus:

The Advanced Microcontroller Bus Architecture (AMBA) was introduced by ARM Ltd in 1996 and is widely used as the on-chip bus in System-on-a-chip (SoC) designs. It consist of following three buses.

- The Advanced High-performance Bus (AHB)
- The Advanced System Bus (ASB)
- The Advanced Peripheral Bus (APB).

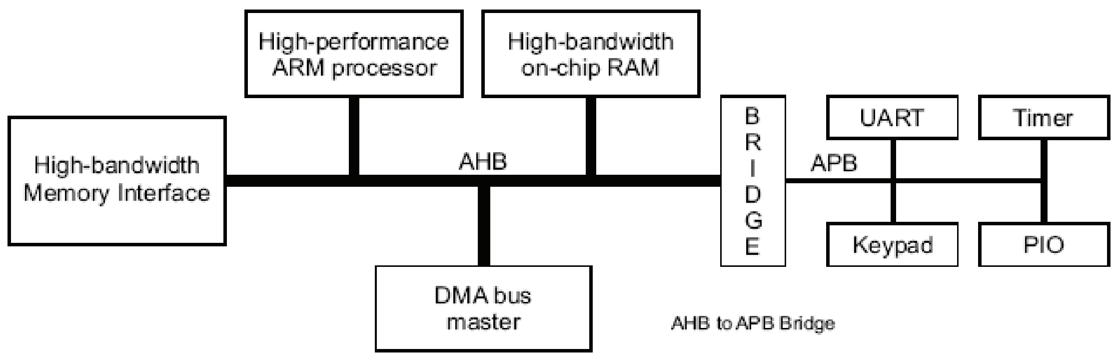

Fig. 4. Block Diagram of AMBA Bus

Design of Proposed Automotive Embedded Controller

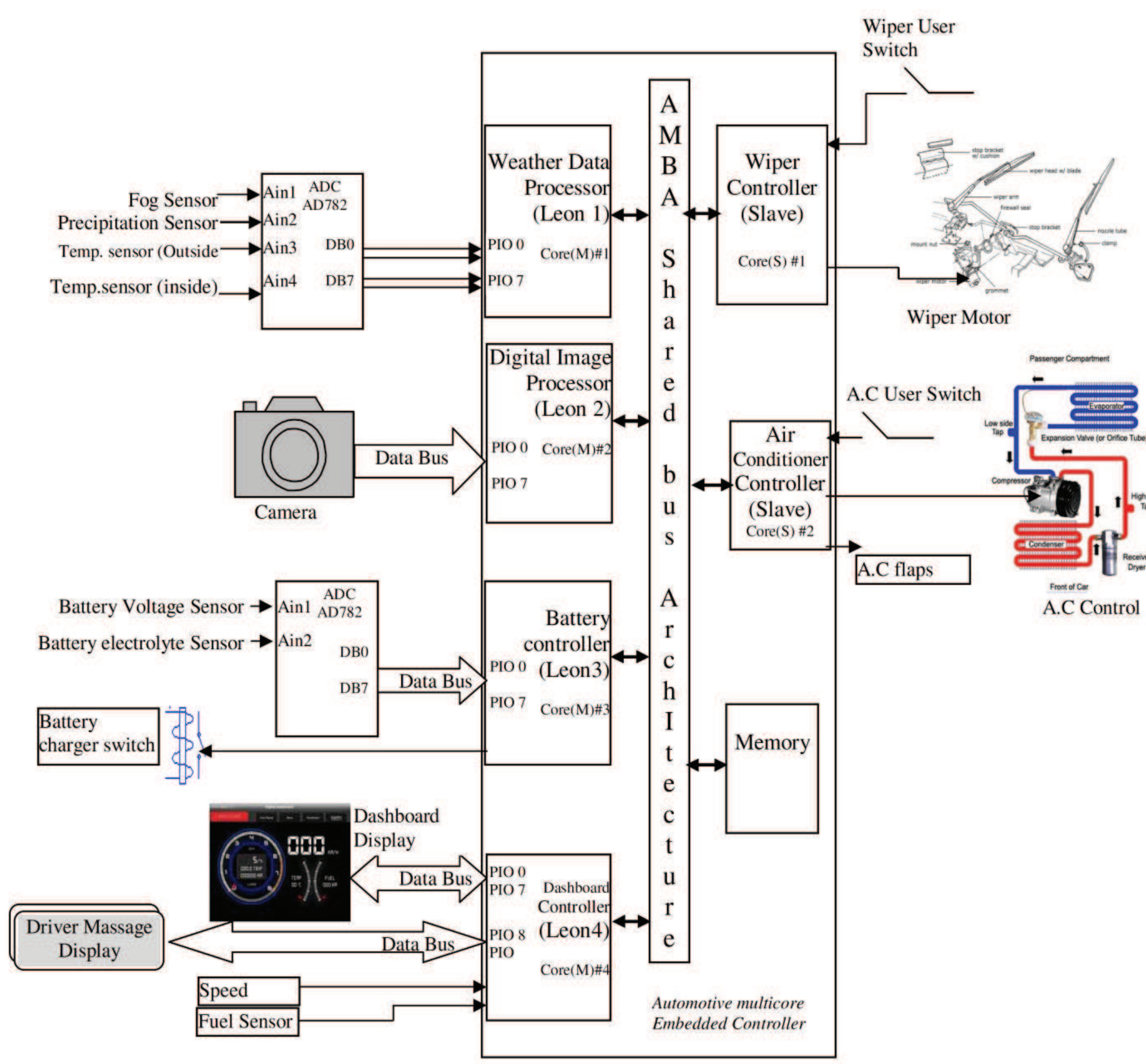

Fig. 4. Automotive Embedded Controller

An embedded controller prototype proposed here utilizing same sensor data for multiple processor cores and optimizing the design by reducing number of individual microcontrollers. This will lead to optimize the resources, cost & power in controlling of in-vehicle gadgets. An Automotive Embedded Controller for multi-application and controlling multiple gadgets is shown in figure 4.

3. Some applications of multicore automotive embedded controller

The above explained system can be effectively utilized for the controlling of vehicular applications. Some of the applications are discussed as below.

3.1 Wiper controlling

Wiper motor controlling is a basic application in case of vehicular controlling. Figure 5 shows weather data processor and Digital image processor as master processor and wiper controller as a peripheral controller. The internal core (mater and peripherals) are connected with AMBA shared bus.

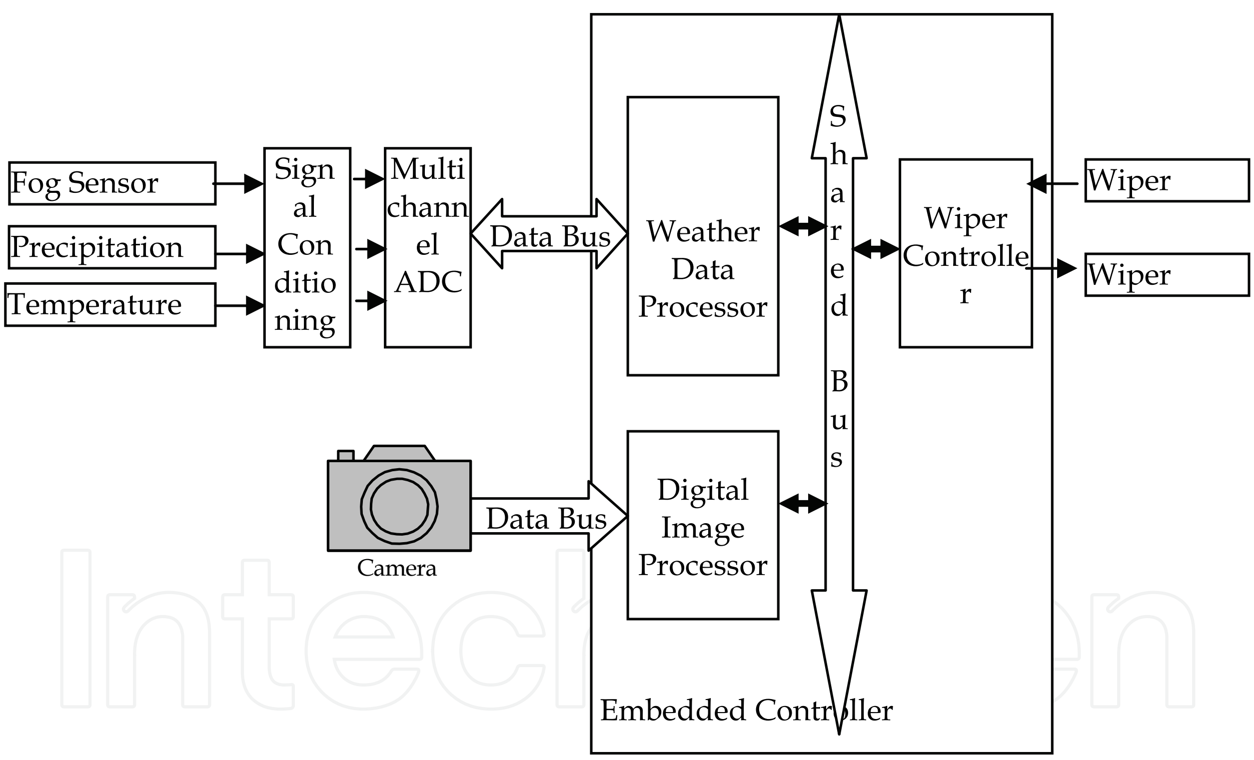

Fig. 5. Block diagram of Multicore Embedded controller for wiper control.

Weather Data Processor: It is a processor processing the data coming from the different sensors regarding weather condition outside and inside the vehicle. For this application three sensors are utilized., precipitation sensor will sense the rain fall outside of vehicle.
According to the data coming to weather sensor, weather data processor will decides the weather condition and inform to other respective core (masters or peripherals) regarding the same for necessary action. In case this processor justify that there is raining condition, it will send data or command to wiper controller. This can be explained from flow diagram 6

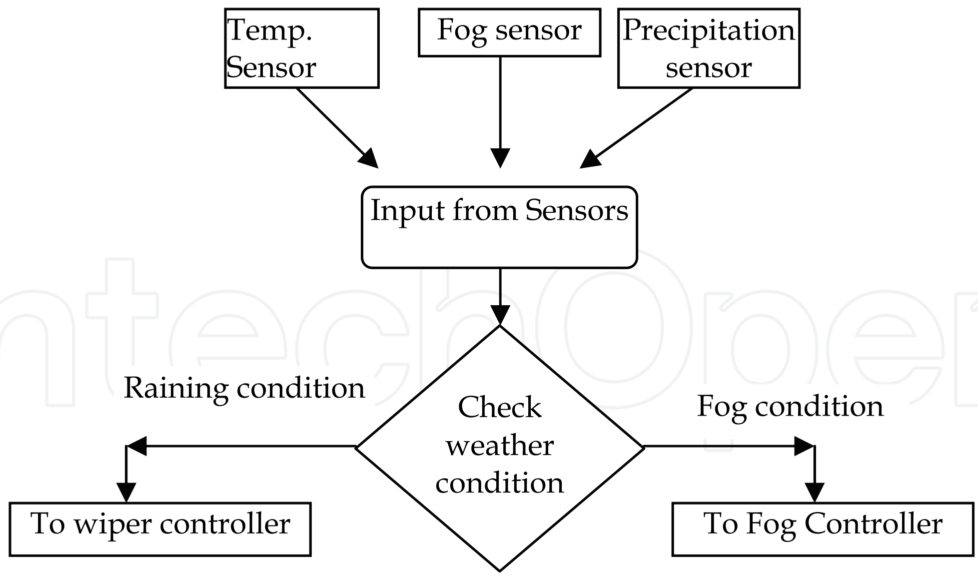

Fig. 6. Flow diagram of functioning of weather data processor

Digital Image Processor: This processor processes the digital images captured by video camera placed aside of driver seat. If this processor identifies dust on front window glass, it will communicate with wiper controller to switch on the wiper for short duration to clear the dust. This action can be understand by flow diagram shown in figure 7.

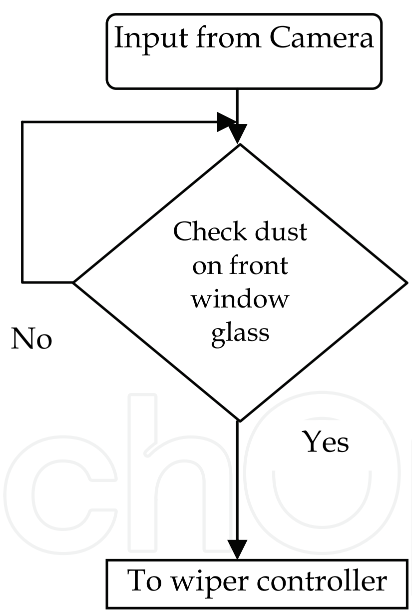

Fig. 7. Flow diagram of Digital Image processor

Wiper controller: This is a peripheral core, allotted the task of wiper motor controlling. This receives data from multiple masters, as shown in figure and accordingly control the wiper motor. Wiper motor will switch on in three different conditions.

- By switching on the user wiper switch
- As per communicated by Digital Image Processor (if there is dust on front window glass). In this wiper motor will switch on for short duration.
- As per communicated by weather data processor. (if raining condition is identified)

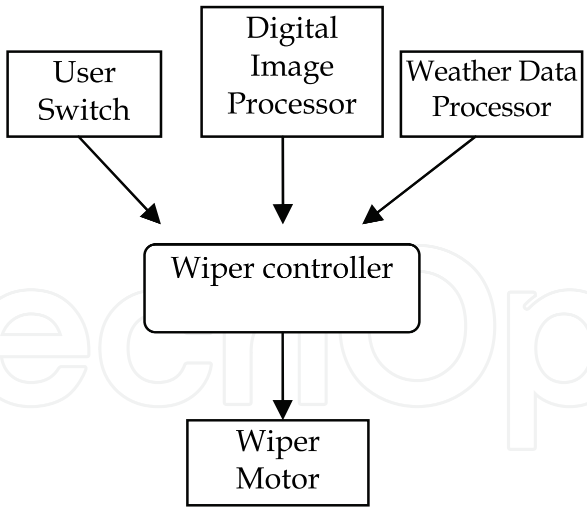

Fig. 8. Flow diagram of wiper controlling application.

3.2 Air conditioning system

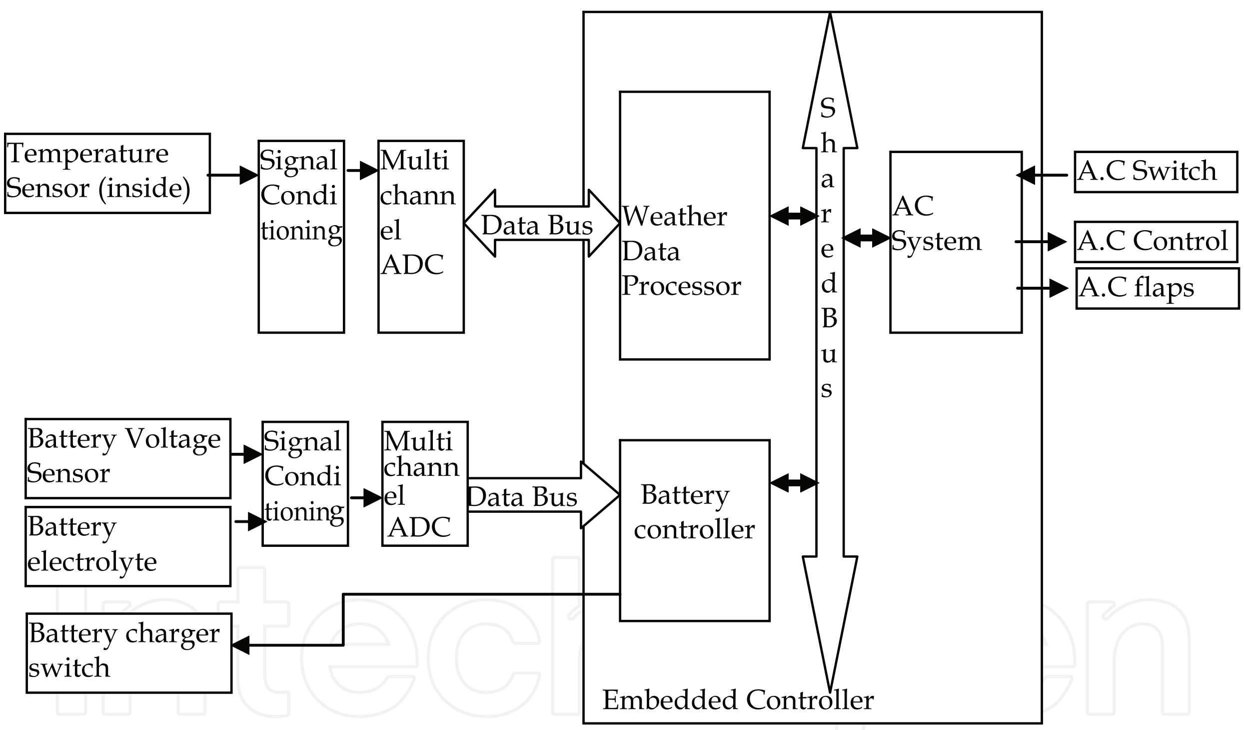

Fig. 9. An Embedded controller block diagram for Air conditioning system

Air Conditioning systems deliver air to the vehicle interior to provide comfort to passengers. These controller typically have control several motors (for blower and flaps), based on different inputs (e.g., temperature). Figure 9 shows block diagram of an embedded controller. This controller consists of weather data processor and battery controller as master and Air conditioning system as slave.

Weather Data Processor: It is a processor processing the data coming from the different sensors regarding temperature condition inside the vehicle. According to the data this processor will decides the hot condition in the vehicle and communicated to AC system (peripheral) for necessary action.

Battery Controller: This processor monitor the battery condition of vehicle and responsible to take necessary action. It will monitor the charging of battery, if battery get overcharge, it will stop charging and vice versa. It also monitors the lever of electrolyte in the battery and warns the driver accordingly by communicating to other inbuilt core related to driver monitor display.
In case of low battery, this processor will communicate with air conditioning module to tern it off to save the battery. Figure 10 shows working flow of this processor.

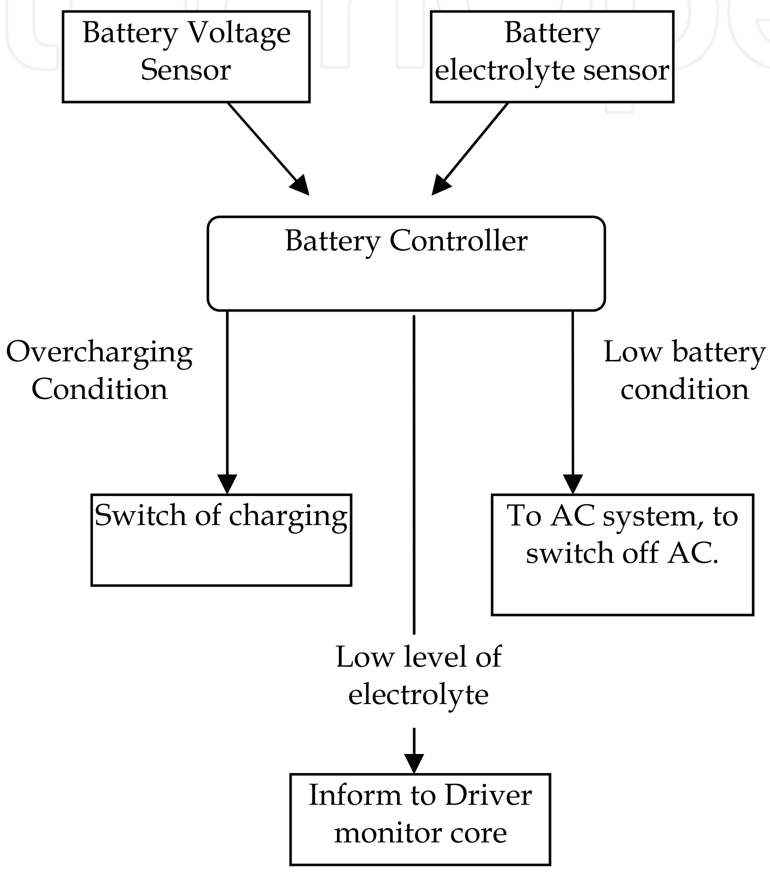

Fig. 10. Flow diagram of working of battery controller

Air conditioning system: It is a peripheral core responsible to control all function of vehicle AC. It receives user switch input as well as other command from weather data processor and battery controller regarding the operating of AC.

3.3 Driver alert massage display

In modern era, passenger safety and safe drive is one of the most hot issue in automotives. Safe driving also depends on the driver alertness regarding the surrounding conditions. For example if there is raining or fog condition, driver should get alert readings, and suggestion to reduce driving speed if speed extending the defined value. The system for this can be implemented as shown in figure 12. This consists of weather data processor & Dashboard display controller. Both core are having processing power are master core interfaced with AMBA shared bus architecture.

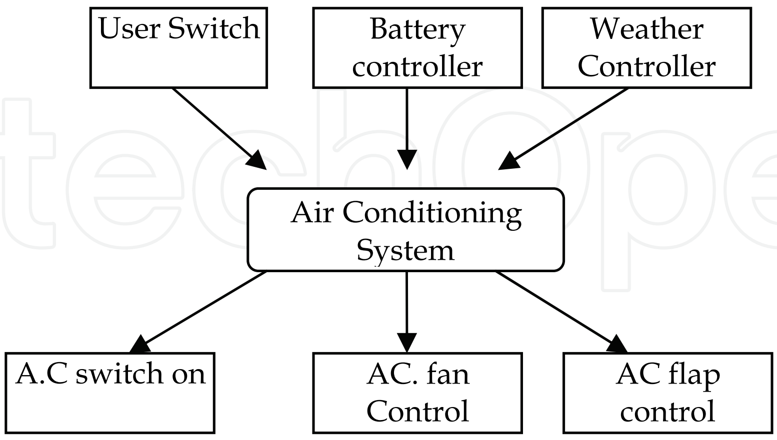

Fig. 11. Working of AC control system

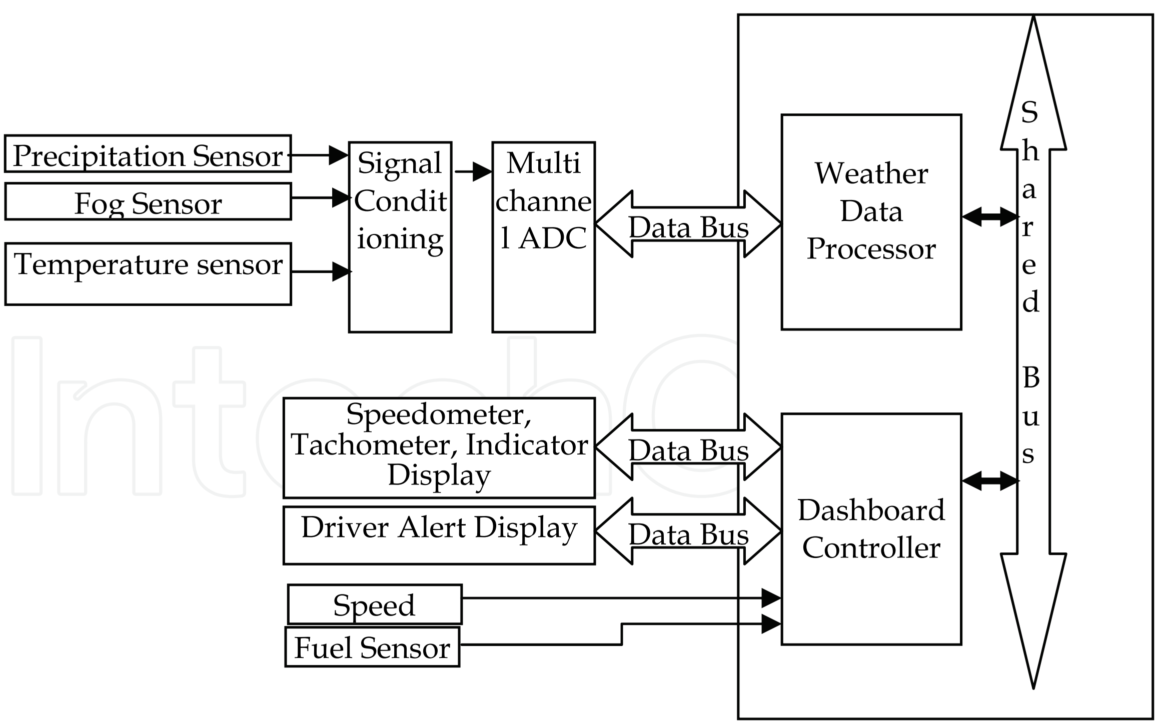

Fig. 12. Embedded controller for driver alert massage display

Weather Data processor is sensing the weather condition as explain in previous section. It is sharing the weather condition with dashboard controller.
Dashboard controller: It is a processor processing data related to dashboard display. Mainly it is handling two displays.
Dashboard display- This digital LCD displays speed, distance in Km, fuel level, indicator condition etc.
Driver alert display- This display is use to display certain information to driver related to car. Example information of weather, car engine over temperature, any linkage in car, security issue in car, emergency massages propagated by road side base stations, massages of inter vehicular communication or particular sign detection by in-vehicular camera. This display will be placed just side to dash board display and easily seen by driver.
In this application weather data processor will process the sensor data and decides the environment condition like raining condition or fog condition. The information will be communicated to dashboard controller to display on alert display. Also dashboard will see the speed of vehicle, if it found more speed it will display massage regarding lower down the speed of vehicle.

4. Conclusion

The embedded system for an automotive control system can be effectively design by extracting the benefit of multicore SoC technology. An integrated automotive controller can be design by using homogeneous or heterogeneous multiple cores (processors) connected with the shared bus like AMBA. The architecture will give better result with efficient resource sharing like peripheral device and memory.

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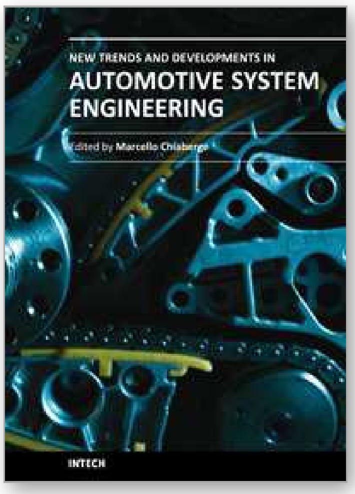

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In the last few years the automobile design process is required to become more responsible and responsibly related to environmental needs. Basing the automotive design not only on the appearance, the visual appearance of the vehicle needs to be thought together and deeply integrated with the â€œpowerâ€ developed by the engine. The purpose of this book is to try to present the new technologies development scenario, and not to give any indication about the direction that should be given to the research in this complex and multi-disciplinary challenging field.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
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