HARDWARE IMPLEMENTATION OF INTELLIGENT BRAKING SYSTEM

S. N. Sidek and M. J. E. Salami

Faculty of Engineering,
International Islamic University Malaysia,
Jalan Gombak, 53100 Kuala Lumpur, Malaysia.
Email : snaim@iiu.edu.my, momoh@iiu.edu.my

ABSTRACT

Intelligent braking system has a lot of potential applications especially in developed countries where research on smart vehicle and intelligent highway are receiving ample attention. The system when integrated with other subsystems like automatic traction control system, intelligent throttle system, and auto cruise system, etc will result in smart vehicle maneuver. The driver at the end of the day will become the passenger, safety accorded the highest priority and the journey will be optimized in term of time duration, cost, efficiency and comfortability. The impact of such design and development will cater for the need of contemporary society that aspires quality drive as well as to accommodate the advancement of technology especially in the area of smart sensor and actuator. The emergence of digital signal processor enhances the capacity and features of universal microcontroller. This paper introduces the use of TI DSP, TMS320LF2407 as an engine of the system. The overall system is designed so that the value of inter-vehicle distance from infrared laser sensor and speed of follower car from speedometer are fed into the DSP for processing, resulting in the DSP issuing commands to actuator to function appropriately.

Keywords: Smart vehicle, hardware implementation, DSP

1. INTRODUCTION

Intelligent braking system has found a lot of potential applications in countries like United States, Japan, Germany, France etc. Researches on smart vehicle are dated back to early 70's. Despite that, it is not until early '90 where it starts to be carefully planned and clearly defined after gaining support from governments and private agencies. The result is a comprehensive, long-term project called Intelligent Vehicle Highway System or later been called Intelligent Transportation System. The system when integrated with other subsystems like automatic traction control system, intelligent throttle system, and auto cruise system etc will result in a smart vehicle. The driver at the end of the day will become the passenger, safety accorded the highest priority and the journey will be optimized in term of time duration, cost, efficiency and comfortability. Currently, the need to have driver to put control over certain functions has become indispensable. This is to alleviate certain problems of liability to some degree when accident occurs. It seems logical that the driver will gradually transfer control one function at a time to the automated system before the system deployment are totally unfold.

In the design of intelligent braking system, the driver is allowed to overtake the handling of the brake pedal from the controller. This is due to the lack of capability of machines to classify and predict certain actions. Machine on the other side, has great information processing power and its ability to withstand the aging has always put it ahead of human. With the advancement of microcontroller technology, the emergence of digital signal processor has seen a lot of successful achievement specifically in industrial control. This paper discusses the implementation of intelligent braking system hardware using digital signal processor as a heart of the system and the communication link between sensor, actuator and other peripherals. To achieve this, the infrared laser sensor will input the value of inter-vehicle distance into the DSP for signal processing which later commands the actuator with appropriate signaling.

2. SENSOR

The choice of sensors to measure the inter-vehicle distance has been discussed thoroughly in [1]. Besides the capability of infrared laser sensor to measure the long distance range (at least 100 meter), the respond time, cost efficiency and the size have been put into consideration for this application. There are several ways to configure and position the sensor so as to have the best measurement, see [1,2]. For the implementation of the system in this research, the vehicle will be equipped with four-beam infrared laser sensor as illustrated in Fig. 1.

This configuration will enable the detection of preceding vehicle on road bends. The tightest relevant radius on the highway (especially in the highway exit) is taken to be 500 meter. In such case, the horizontal aperture angle must be at least 8 degrees for an inter-vehicle distance of 75 meter. The vertical aperture is fixed to be 1 degree and is positioned in such a way to avoid fault reading due to the road conditions. To obtain this configuration, the four-beam infrared laser sensor is arranged next to each other in one lateral plane. The outputs of this sensor are then connected to an integrator before being fed into the embedded DSP through P2 (expansion analog connector). Each beam of the sensor delivers signals every 100 ms. Thus, at every clock, at least four sets of readings are received. For this research work, only part of highways, which is straight in nature is studied. For that reason only the reading from the two beams in the middle will be focused on. The other two readings are possible to be utilized, when they are to detect the inter-vehicle distance while in the road bend. As such, another sensor is needed to monitor the steering angle so as to determine the degree of the curve road in which is necessary to decide which laser sensor readings are to be used. In general, these basic distance readings suffer from serious degradation to certain extent, that is, there could be great difference in the measured values as compared to the ideal value used in the simulation study. In practice, the signals received may be reflected from traffic signs, guidepost, and crash barrier. For that reason, a special corrective measure can be induced to preprocess this signal before being sent to DSP. On the other hand, using data extrapolation from look-up table or knowledge based system can be another approach to solve the above problem.

Alternatively, each vehicle can be equipped with a special tag that can reflect unique signal to be sensed by the detector of the sensor.

3. ACTUATOR

The actuator of the system is part of a module called Auxiliary Hydraulic Module (AHM). The function of the module is to provide input force to the vacuum booster through an actuator and brake pedal. Output signal from the DSP controller is in the form of pulse width modulation (PWM) and is amplified using power amplifier. AHM later processes this signal and generates necessary pressure against the brake pedal. PWM is a square wave signal of fixed frequency but varied duty cycle. It is possible, by varying the duty cycle, the output force and the brake pedal can be controlled.

As shown in Fig. 2, AHM consists of an arrangement of hydraulic pump, valves and actuator. If the hydraulic pump draws off a constant amount of fluid through the valves while the valves are opened, no pressure is developed but once it closes completely, an abrupt rise of pressure is attained. By switching the valves at high frequency (typically 100 Hz), coupled with duty cycle which is changeable, the pressure inside the cylinder of the actuator can be controlled. Eventually, this pressure pushes the piston of the actuator and applies appropriate force to the brake pedal. At the maximum value of duty cycle, which implies the valve is opened for most of the time, no force is applied to the brake. The mapping from the duty cycle to the brake line pressure has been discussed in [4]. The result suggests that the brake model can be approximated by the first order system.

4. CONTROLLER

The technology of DSP features the cross between microprocessor and microcontroller technology. In most of specific driven applications, real time operation, compact and small scale circuitry coupled with high processing speed are always required. By having Harvard type architecture, the DSP is able to have a parallel processing by maintaining two separate bus structure namely program and data buses, and the special instruction set allows the processor to go for full speed execution [5,6].

The TMS320LF2407 is a fixed-point processor optimized for control applications. It has integrated on chip ADC module, PWM module, memory expansion capability, relatively high speed (30 MHz) and several logging port options [7,8] which are necessary for system under study.

The system employs Sugeno fuzzy inference system as a kernel to the controller. It takes two inputs from the sensors namely the inter-vehicle distance and follower vehicle speed, whereas the PWM output signal is generated from already fine-tuned thirty sets of rules to operate the actuator. The tuning process is done using Matlab software through the adaptive neuro fuzzy approach with back propagation algorithm. The Matlab generated inference system file then being downloaded into the DSP. This allows the off-line batch updating for the inference system if the input output data pairs are available.

Fig. 3 shows a brief system architecture, where one of the dual event managers is utilized. The general-purpose timer triggers the fetching of data from analog expansion port (P2) and activates the interrupt service routine for every each 100 ms. The on-chip PWM module will output the scaled signal and sent to the power amplifier before finally drive the actuator. By adding the integrator circuit the cost of additional circuit is worth it to secure the accuracy of sensor reading. The 10 bits ADC can have a resolution up to 0.146 meter following equation (1) compare to the using of on chip counter, which capable to have a resolution of 5 meter[1].

$$Re\,solution_{ADC} = \frac{(3\times 10^{\wedge 8})\times(1\mu\,sec/ADC-bit(decimal)}{2}$$

$$Re\,solution_{Counter} = \frac{(3\times 10^{8})\times speed\ of\ counter(sec)}{2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

5. CONCLUSION

TMS320LF2407 is an efficient processor to handle the task to control the intelligent braking system. The on board peripherals reduce the cost of additional component and the architecture allows real time control. The performance of the processor can be enhanced if there is special fuzzy logic instruction set available in the software kernel of the processor.

References

1. Salami M.J.E., Sidek S.N., "Design of Intelligent Braking System", Proc. TENCON 2000, vol. II, Kuala Lumpur
2. Nocker G., Muller R., "Intelligetn Cruise Control with Fuzzy Logic", Daimler-Benz AG, Forchung und Technik.
3. Maretzke J., Jacob U., "Distance Warning and Control as a Means of Increasing Road Safety and Ease of Ooperation", Volkswagen AG, Germany, 389/359 ImechE 1992
4. Reza H., Xu Z., Yang B., Ioannou P.A., "Modeling and Control Design for a Computer-Controlled Brake System", IEEE Trans. On Control Systems Technology, Vol. 5, No. 3, May 1997
5. Popovic D., Vlacic L., "Mechatronics in Engineering Design and Product Development", Marcel Dekker, Inc. 1999
6. Lilein A.L., "Digital Signal Processors vs. Universal Microprocessors", ESIEE Paris, SPRA344, Sept. 1996
7. TMS320LF2407 Evaluation Module Technical Reference, Spectrum Digital, August 2000
8. TMS320LF2407, TMS320LF2406, TMS320LF2402 DSP Controllers, SPRS094E, August 2000

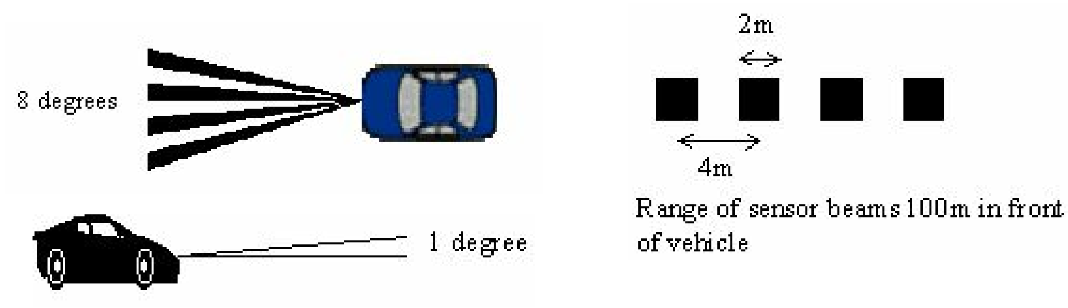

Figure 1: Sensor Positioning and Characteristic

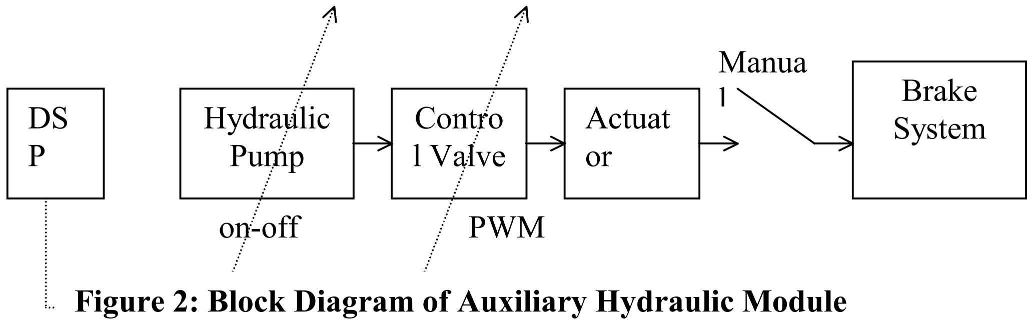

Figure 2: Block Diagram of Auxiliary Hydraulic Module

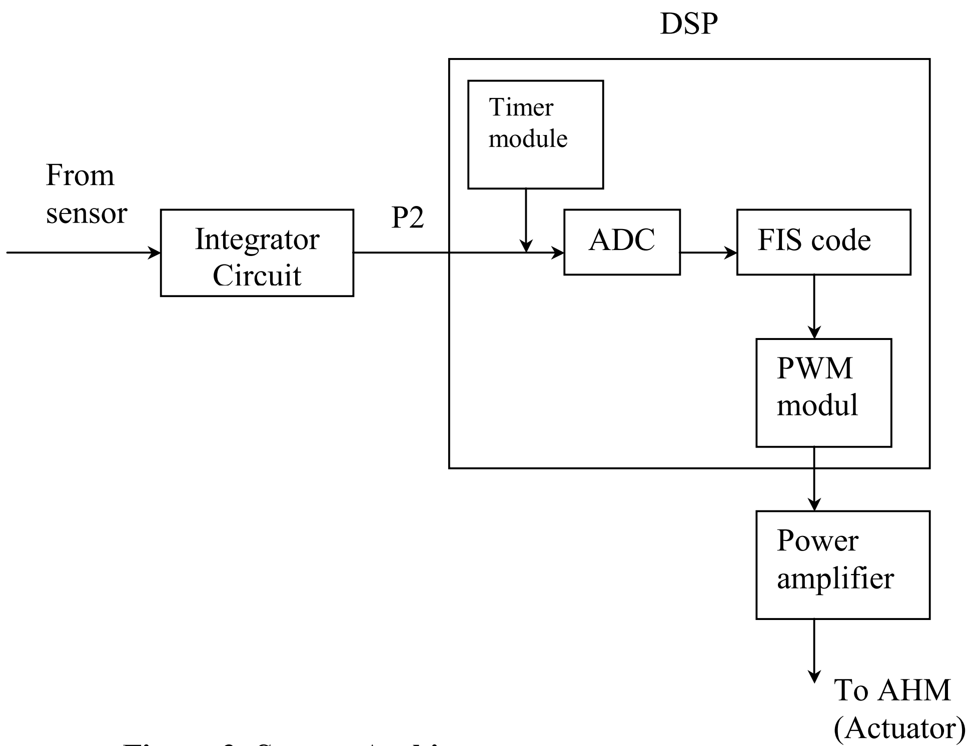

Figure 3: System Architecture