Design of a Low Cost Electronic System for Automotive Steering Controlling

C. A. Calva, M. F. Rocha, L. Orozco, M. I. Rocha Gaso, M. R. Osnaya, R. Navarrete, E. Andrade, and C. Solis.

***Abstract*—This paper presents the design of an electronic system developed on microcontroller-based technology to control an automotive steering system. The purpose of this development is to get a quality system of low cost and to reduce mechanical components in the system, gaining passive security and maintaining active security in the vehicle. Assisted with specific software for programming, PCB designing and variable simulation it is possible to adapt the operating conditions of the system according to the specific characteristics of each vehicle Using PID control statements, the advantages of embedded systems and low energy consumption this design pretends to offer a reliable option reducing components, costs and being environmentally friendly.**

***Index Terms*—Embedded system, microcontroller, PID control, steering system.**

I. Introduction

The automotive industry has distinguished itself by introducing the most advanced manufacturing and technology in its developments, and it is because electronics has grown tremendously in recent years that the evolution of automotive systems have been imminent.

Automotive Steering systems are no exception, now hydraulic steering systems have been replaced by electrical and electronic systems, however hydraulic and electro-hydraulic systems still prevalent in the market, the question is why. The reason could be that these systems represent low cost in production and their performance is acceptable according to the standards of design and operation nowadays.

Unfortunately the electronic systems are only suitable for luxury vehicles that offer the different companies and one of the reasons is because they are still expensive compared to conventional systems.

The electronic vehicle systems offer many advantages such as reduction of mechanical elements, lower power consumption, flexibility in their operation and is environmentally friendly.

Embedded systems were created from the need to integrate all the elements to solve different problems without having to add or remove devices. Their structure allows them to have reliable operation through full compatibility between components and the ability to interact with other devices and systems through communication protocols used, plus they are cheaper compared to a system designed specifically for a purpose.

Considering further that hybrid and electric vehicles evolve satisfactorily, it is necessary to consider the inclusion of mechatronic steering systems where mechanical components are replaced mostly by reducing vehicle weight and increasing passive safety.

According to a Frost & Sullivan report, it is expected EPS Systems to almost completely overtake HPS systems by 2020 in Japan and it would take more time in Europe and USA.

Statistics like the previously mentioned are not good for the electronic steering system future considering the inclusion of electronic and mechatronic systems in other areas as braking and suspension systems included in medium and high-class vehicles.

Designing and developing low cost steering systems and prototypes is the right goal to improve their applications in all sectors of the industry.

In Mexico there are not many developments in this sector because the research is concentrated in the countries which have automotive industries. Universities give the students the opportunity to design and develop solutions for industry through research programs and industrial links. To get the goals in electronic developments it is necessary to develop low cost devices to integrate systems in all automotive industry, with the only intention of being environmentally friendly.

Reducing the mechanical elements in the system there would be a saving of natural resources and increasing passive security, reducing the probability of injuries caused by metallic components launched toward passengers.

II. Electronic Steering System Design

The existing electric and electronic steering systems offer solid bases in the parameters and statements. The purpose of the steering system is to control the direction of the vehicle moving the angle of the front (and also in luxury cars rear) wheels. The driver controls that angle by rotating the steering wheel in the front panel of the vehicle, and in the classic steering systems the relation between the steering wheel angle and the wheels is determined by a mechanism which could be Column Type, Pinion Type, Rack Type or Double Pinion Type (Fig. 1).

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Fig. 1. Classical types of mechanisms in the steering systems.

In electric and hydraulic steering systems the mechanism is assisted by an electric motor or an oil pump coupled, reducing the effort to the driver while rotates the steering wheel. In all cases the sensibility of the mechanism is controlled by the vehicle speed, the higher the velocity the lower the sensibility of the steering wheel. The ratio of sensibility depends of each vehicle and its dynamic characteristics and stability. The problem with the classical systems is that there are many mechanical elements

The standard installation scheme (Fig. 2) of steering systems could cause injuries to the passengers of the vehicle in case of accident due to the amount of metallic components which may be broken and launched toward the passengers, affecting mainly the area of the legs.

Fig. 2. Schematic image of the steering system location in the vehicle.

A. Determining the Parameters Involved

The parameters which are mainly included in the control models are: Speed of the vehicle, the Steering Wheel angle and the battery voltage, which is needed to energize the electric motor in the steering mechanism. The scheme of the embedded system to satisfy those requirements (Fig. 3) shows the interaction between sensors, microcontroller and actuators.

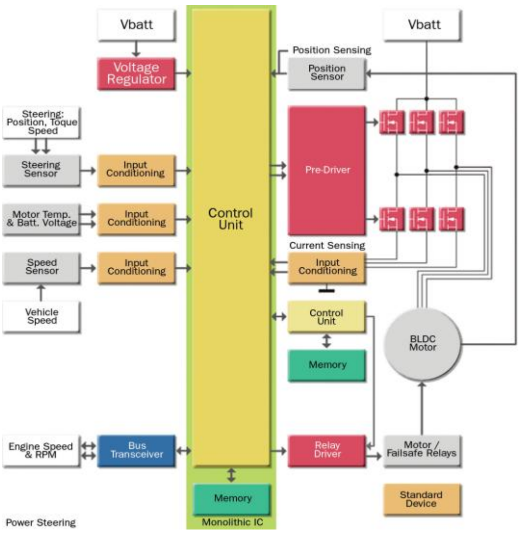

Fig. 3. Embedded diagram of electronic steering system.

B. Determinind Microcontroller Hardware

For the embedded system it was decided to use PIC microcontrollers because they are low cost devices and the Family 18FXXX supports SAE standards that are of common use in automotive components and systems.

The microcontroller that was chosen is the PIC18F452 (Fig. 4). This device is electrical-noise resistant and supports CAN-BUS communication protocols, it may be programmed using C Language with the appropriate compiler software and its cost is about 10 dollars, characteristics.

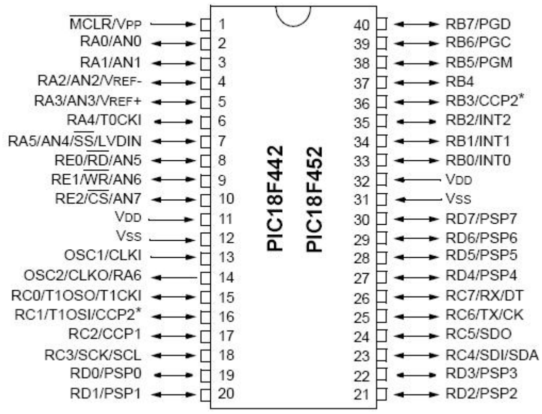

Fig. 4. Microcontroller pin configuration.

C. Sensing Conditions

According to SAE standards for sensing response, the characteristics of the sensors must accomplish the following requirements. For the steering wheel position and speed sensor, critical parameters include:

- Angular range: ±900 °(±2½ turns)
- Angular resolution: 0.1 °
- Angular accuracy: ± 1 to ± 2 °
- Response time: < 10 ms
- Dynamic range: up to 2000 °/s
- Standby current: < 100 µA (ideally zero)

For steering torque, the critical parameters are:

- Torque range: ± 10 N-m;
- Accuracy:
- 1% full scale around "zerotorque"

o 3% to 5% full scale elsewhere

o Response time: < 500 µs

- Standby current: < 100 µA (ideally zero)

The final sensing requirements in motor position and speed in the brushless dc (BLDC) commutation are:

- Rotation speed: up to 15000 rpm;
- Angular resolution: < 0.1˚;
- Angular accuracy: ±1˚;
- Speed resolution: <2 rpm;
- Speed accuracy: ±5 rpm; and
- Response time: <100 µs.

D. Control Aspects

The International Electrotechnical Commission (IEC) with the IEC 61508 standard addresses the functional safety of electrical/ electronic/ programmable electronics (E/ E /PE) safety-related systems, however, the IEC standard does not explicitly state the requirements for features or capabilities, it only does establish criteria for system designers. Today, meeting the criteria could mean using two CPUs for redundancy in a safety system. One CPU performs the activity and the other monitors the first's behaviour as a watchdog. To increase the reliability of the systems the number of the components presents in the system must be as small as possible.The parameters which are mainly included in the control models are: Speed of the vehicle, the Steering Wheel angle and the battery voltage, which is needed to energize the electric motor in the steering mechanism. The scheme of the embedded system to satisfy those requirements (Fig. 3) shows the interaction between sensors, microcontroller and actuators.

III. Results

Simulation is a very important aspect in design because it offers preliminary tendencies of the behaviour of the model.

The first step to simulate was to create an interface where the input data (the values of speed, steering wheel angle and battery voltage) is written in two different ways, one is typing a static value to observe the steady behaviour and the other is as a function to observe the dynamic response of the system. When the interface is finished, in the main program the model equations and PID constants are edited according to the design and they are modified by analyzing the results of a first simulation, if not another test is executed changing the values of the PID constants (Fig. 5).

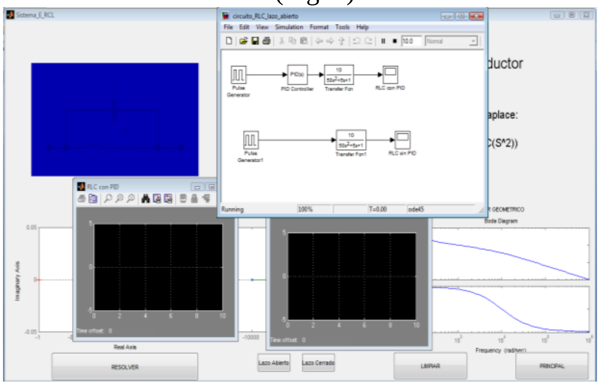

Fig. 5. Interface programmed on Simulink software for the steering system modeling.

The Block Diagram of the PID Control is a schematic expression of the mathematic model of the Transfer Function of a System and it is common used in MATLAB, in those diagrams is easy to see and comprehend how the variables influence in the System. The Block Diagram used for this System (Fig. 6) is of closed-loop type, because of the PID control needed to adjust the value of the input parameters according to the output response.

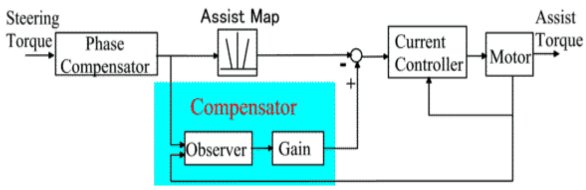

Fig. 6. Block diagram of closed-loop type used for the system modeling.

Once the simulation has given the expected results, the next step is to program the microcontrollers. To make it possible it was used compiler software to convert the language used by the programmer into a hexadecimal code for the microcontroller. The software used is PIC CCS because it has better compilation tools for control and communications applications.

The next step is to simulate the electronic circuit response, it was used the software PROTEUS to create real time simulations, this software offers many libraries and tools containing all the electronic devices needed for the design. The simulation screen is shown in (Fig. 7).

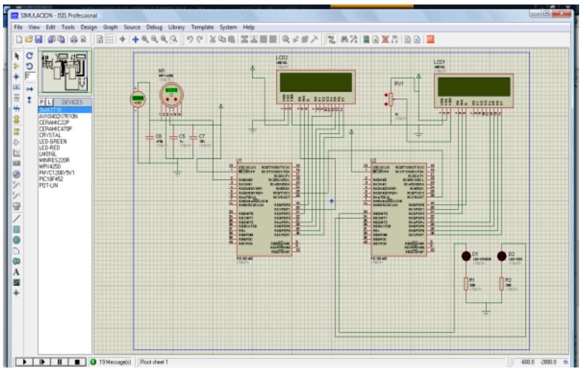

Fig. 7. Electronic circuit simulation of the embedded system.

Finally, to design the Printed Circuit Board it was used the tool ARES of PROTEUS software, merging the simulation circuit design and editing the board area to obtain the circuit track and the components placement. The model can be observed in the computer (Fig. 8) to determine if the placement of the electronic devices is the most convenient to obtain a good performance.

Summarizing, to develop good designs in the industrial context it is necessary to use diverse tools and include multidisciplinary studies. In this case, the first step was to create the control model based on the parameters included in this phenomenon, then choosing the most adequate hardware according to the objectives of this project and finally simulate the model behaviour based on PID control statements. The objectives always have to be the environment and safety of the passengers in the vehicle.

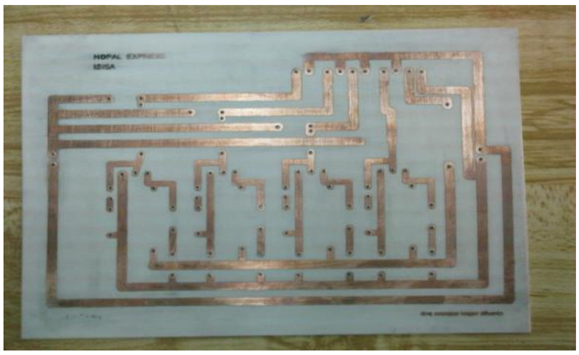

Fig. 8. PCB Sample designed for this proyect.

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