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ELECTRONIC STEERING OF AUTOMOBILES

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ABSTRACT

In a conventional steering system, the steering action is achieved using a rack and pinion gear box arrangement causing more frictional losses and tends to increase the weight and space occupied at the frontal portion of the vehicle. The driver might also get hurt by the steering column in case of an accident. Also it is not possible to achieve a variable steering feel depending on the driver feedback.

The main objective of this project is to overcome these constraints and achieve a safe steering system. It is proposed to design and implement a Steer-By-Wire system. In this system steering action is achieved by the usage of electro-mechanical components.

In this project an accelerometer mounted on the steering wheel is used to monitor the angle of the steering through the output voltage produced. This voltage is fed into a microcontroller. The micro controller contains the necessary algorithms which convert the digital value into an appropriate signal which is given to the servo motor through the servo motor drive mounted on either side of the wheels. This produces a rotary motion on the wheels causing wheel tracking.

A mode selector configured along with the micro-controller helps the driver to select different modes depending on the feedback required, thereby achieving over-steer, neutral steer and under steer. The proposed method has been successfully tested on a prototype model

KEYWORDS: Automotive Sensors, Measuring, Adaptive Steering

INTRODUCTION

The conventional steering system and the power assisted steering system are at the peak of development in automobiles. So to aid even better handling and to improve the safety of the driver a Steer-By-Wire (SBW) system has been developed which has no mechanical linkage. The main objectives of the developing trend are enhancing comfort and safety of passengers and vehicle itself. This is achieved with the help of modern electronics there are a lot of chances to decisively increase the safety compared to today's automobiles by making full use of x- by-wire possibilities. Thus the steering action and directional control is achieved by electro-mechanical means rather than relying on a mechanical system.

The main objective of this project is to detect the steering wheel movements by accelerometer and relayed to the microcontroller and it commands the stepper motor according to the control algorithm, then the road wheels moves according to the movement of motor.

Disadvantages of Conventional Steering System

- Increased weight
- More friction due to rolling of mechanical components.

- Steering response cannot be varied.
- Steering column might hurt the driver in case of accident.
- More effort for steering.

Advantages of Steer-by-Wire System

- Non-contact type of steering
- Safer than conventional steering
- Less friction
- Can be programmed to perform as an Adaptive steering
- Less chances of failure in case of accident

BLOCK DIAGRAM OF STEER-BY-WIRE SYSTEM

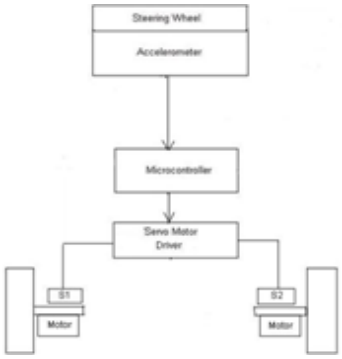

Figure 1

REQUIREMENTS OF ELECTRONIC STEERING IN AUTOMOBILES

- Directional control of the automobiles should be maintained at all possible conditions.
- The road wheels of the automobiles should follow driver's input command and maintain the synchronization with the steering wheel.
- The road wheel system must have a quick response, suitable damping, and minimal tracking error.
- The steering wheel should return automatically to the wheel center.
- The variable steering ratio should improve the vehicle handling performance and vehicle dynamics.
- Yaw rate measurement and correction must be applied for different road conditions.
- Feedback to the driver should be given for varying speeds.
- A redundancy system must be provided to take care of failure situations.

COMPONENTS OF STEER-BY-WIRE SYSTEM

Accelerometer

Non-contacting sensors (accelerometer) are used to overcome the disadvantages of potentiometers in the measurement of angles. A 3-axis accelerometer is used to define the roll angle of the steering wheel from the vertical. This gives output in the form of analog voltages

The 3-Axis Accelerometer sensor will operate between 2.2 and 6 volts. In our project ACC 301 has used which is shown in the Figure 2.

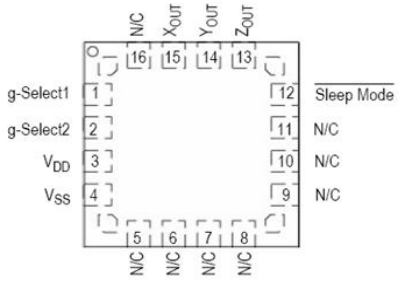

Figure 2: ACC 301 Top-View

PIC Microcontroller

Easy Programming and Erasing are the main features required in our module, since it has to perform as an adaptive type of steering. So PIC 16F877 is used for programming since it offers the flexibility we require in our project.

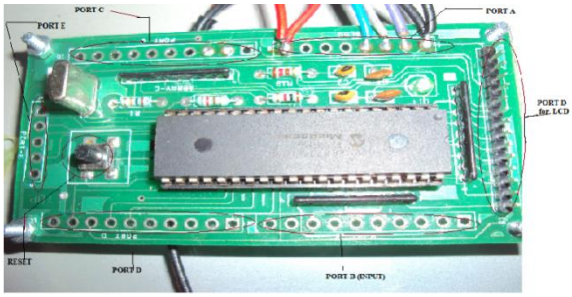

Figure 3: PIC 16F877

Servo-Motor

The main advantage of using a servo motor in place of either a DC motor or a stepper motor is that an error signal generated in the system can be included in the steering action to a give a perfect and accurate steering determined by the driver. In our set-up two servo motors placed at either end of the front two wheels for tracking. This setup eliminates the purpose of a rack and pinion setup thereby releasing space at the front which can be used for other innovative designs of the vehicle.

The servo motors are operated through two separate servo motor drivers, which perform the same action as they have the same programming.

OPERATION

Methodology

- An accelerometer mounted on the steering wheel measures the angular rotation provided by the driver.
- The input voltage of the accelerometer is passed to an ADC and sent to an ECU which depending on the program generates an output signal.
- The output digital signal is passed to a DAC and the voltage is given to the servo motor drivers.
- The servo motors interfaced to the drivers obtain their inputs through them.
- The rotation of the pinion causes the wheel to track in the corresponding direction similar to that of the steering wheel.

- The steering of the wheels is thereby achieved by the movement of the pinions.
- Three pre-determined modes, Mode 1, Mode 2, Mode 3 can be selected on the mode selector which gives Over-steer, Neutral Steer, Under Steer respectively
- A redundancy system is incorporated by a failsafe ECU to give a warning to the driver in case of failure of any of the main systems of the SBW and also to control the vehicle till the error in the main control module is checked and rectified.

Adaptive Steer-by-Wire System

The module in our Steer-by-wire system performs as an adaptive steering depending on the driver input. Different drivers need different steering feedback or based on city or highway driving the steering ratio might have to be changed. To obtain the varying steering actions a mode selector was constructed and placed in the set-up. The mode selector has three modes which are explained below.

Coding for Adaptive Steer-by-Wire System

Coding part on the micro-controller was done using embedded C in Top-Win burner.

OPERATING MODES

Mode 1: Over-Steer Mode

In this mode the input given to the steering wheel is magnified and got as a much larger output. This mode assists driver who needs a sharper driving feel or drivers who need to park the vehicles in tight parking spots.

Mode 2: Neutral-Steer Mode

In this mode the vehicle performs in a neutral state or as a regular vehicle.

Mode 3: Under-Steer Mode

In this mode the input given to the steering wheel is reduced and much smaller output is obtained. This mode can be used by drivers who need a toned-down steering feel or by drivers in highway cruising mode.

SIMULATION RESULTS

The simulation of Steer by Wire system is done using Lab View by National Instruments. In this simulator a Block diagram panel and a Front panel is designed to enable the simulation. The Front panel indicates the components involved while the Block diagram panel contains the functions and scripts used to execute the simulation. In the Front panel a knob calibrated to 0(zero) at the center and varying values at its extremes is used in place of an accelerometer and two horizontal sliders of same values are used as the measurement of left side and right side wheel travelIn the block diagram a multiplier function between the knob and the slider is used as a replacement for the micro-controller program (i.e) by varying the multiplier value the amount of wheel travel obtained will be different for different knob settings.

By the execution of the program from the run command, the variation of wheel travel at the horizontal sliders can be seen on a real time with varying changes on the knob is shown in the Figure 4.

Simulated Circuit

The circuit is simulated using LABVIEW and the simulated output is shown in the Figure 4.

Simulated Output

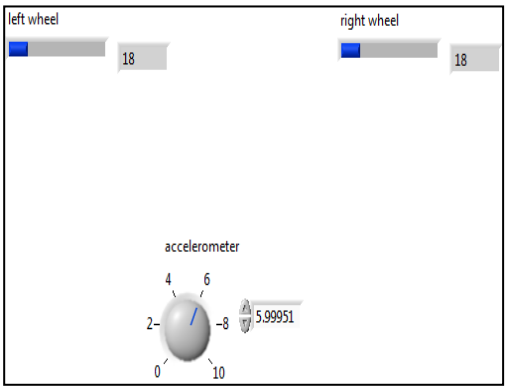

Figure 4: Simulated Output

Test Bench Setup

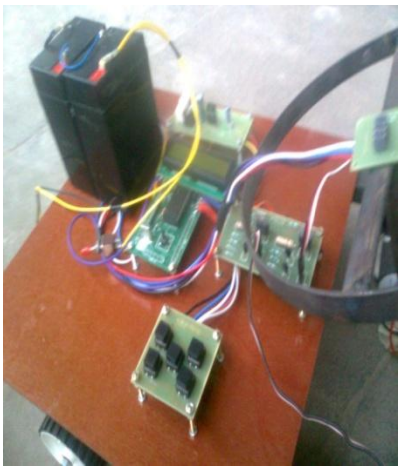

Figure 5: Test Bench Setup

The accelerometer is mounted on the steering wheel. The pinion on each wheel is driven through the stepper motor controlled by the driver circuit through the microcontroller. The micro-controller module along with the other electronic peripherals are mounted and fastened on a board and placed on the frame securely. The weight of the test bench along with all the peripherals is 4.75 kg.

RESULTS AND DISCUSSIONS

Result Validation

When steering action was given to the steering wheel in the three different modes, the following results were obtained A test bench with dimensions 40cm * 25 cm was setup to give an idea about the working of Steer-by-Wire system. The test bench was made of box section mild steel with a thickness of 1.5 cm. The front two wheels are tracking wheels while the rear two wheels are follower wheels. Drive to the front two wheels are given individually through two DC motors. The steering wheel is mounted on the frame without any column support towards the lower end of the frame for steering, since the steering action can be achieved without any mechanical contact from the steering wheel to the road wheels.

Under-Steer Mode

Mode 3 was programmed as an under steer mode and for the same 12^{o} input and the output obtained was 17^{o}.

Neutral-Steer Mode

Mode 2 was programmed to be neutral steer and for the same 12^0 input, it produced an output of 20^0. This output was taken as the reference for calculation of the error in the other two modes.

Over –Steer Mode

Mode 1 was programmed as over steer mode, and in this mode the input given to the steering was 12^o, while the output obtained at the wheels was 36^o. The amount of overshoot is by 11^o. Comparing the under steer and Neutral steer, we observed that the over steer mode produces a overshoot by 11^o.

Analysis

The test setup allows us to come to a conclusion that in the over-steer mode there is fair amount of overshoot, while the other two modes work as programmed. The error in Mode 1 can be reduced by increasing the number of divisions programmed for the rotation of the servo motor.

ADVANTAGES OF SBW SYSTEM

- Since the rack and pinion mechanism has been eliminated, it frees up space at the frontal portion of the vehicle enabling the designers to bring up new design features.
- Usage of a differential or a transaxle can be eliminated in the case electrical vehicle as the front wheels can have individual power supplied to them.

CONCLUSIONS

The design phase of our project included the design and simulation of a steer by wire system. The design part includes the usage of an accelerometer to monitor the tilt angle and drive the stepper motor through a micro-controller. The programs stored in the micro-controller memory can be used to alter the feedback to the wheels depending on the driver input. The simulation part includes a simulator by Lab View produced by National Instruments.

In this section the accelerometer controls the wheels by simulating 2 horizontal sliders and a knob interfaced through a multiplier function. The second phase of our project included the fabrication of a model steer-by-wire system using the design parameters obtained calculations and ergonomic factors. The model system consists of a mode-changer which can used to vary the steering feedback. The model setup was operated in all the three modes and found to have desirable operating characteristics.

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